PRINCETON APPLIED RESEARCH®

Return to Code 6510

INSTRUCTION MANUAL

ELECTROMETER

Model 134

MP MASTER

MA29046

PRINCETON APPLIED RESEARCH CORPORATION

PRINCETON, NEW JERSEY

INSTRUCTION MANUAL

ELECTROMETER

Model 134

THIS MANUAL APPLIES SPECIFICALLY TO MODEL 134 SERIAL NO.

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NOTE: Material relating to changes, if any, will be found in envelope at rear of manual.

M176; 8/72

WHEN YOUR EQUIPMENT REQUIRES SERVICE

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B. If it is necessary to send any equipment back to the factory, we need the following information.

(1) Model # and serial #.

(2) Your name (instrument user).

(3) Your address.

(4) Address to which instrument should be returned.

(5) Your telephone number and extension.

(6) Symptoms (in detail, including control settings).

(7) Your purchase order number for repair charges (does not apply to repairs in warranty).

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SECTION I
CHARACTERISTICS

1.1 INTRODUCTION

The PAR Model 134 Electrometer is a highly sensitive, solid-state, dc multimeter, incorporating the latest advances in MOS (metal-oxide-semiconductor) technology and high-impedance low-current circuit design. The result is an instrument with unequaled performance with respect to voltage and current stability, noise, and ease of operation.

The Model 134 functions as a high input resistance voltmeter, a versatile ammeter, an ohmmeter, a coulombmeter, and a general-purpose low-level amplifier. Additional features include operation as an extremely accurate unity-gain amplifier, for use in buffer applications, voltage and current recorder outputs, operation as a true constant current source featuring extremely high output resistance and excellent stability, nearly total freedom in all modes of operation from wide variations in line voltage and transients, and input overload protection on all ranges to 600 volts.

As a voltmeter, the Model 134 is characterized by a very high input resistance, greater than 10^{14} ohms. The input resistance can also be varied from 10^{12} ohms to 100 ohms. The full scale sensitivity ranges from 100 V to 1 mV, with a resolution of 30 μV on the 1 mV range. These features, combined with excellent voltage stability as a function of time and temperature, enable the Model 134 to be utilized accurately and easily in low-level measurements from high-resistance sources, and in general-purpose laboratory applications.

Operated as an ammeter, the Model 134 can be operated in either a shunt or feedback configuration. Shunt operation involves current measurement by reading the voltage induced by the signal current across built-in range resistors, selectable from 100 ohms to 10^{12} ohms. Feedback operation is employed where freedom from the slowing effects of input shunt capacitance is desired, and where the ammeter input resistance and voltage drop are required to be very low. Thus, near-ideal ammeter performance is obtained with good speed of response and low noise. Full-scale current ranges are from 100 mA to 10^{-14} A, with resolution to better than 10^{-15} A on the most sensitive range.

The Model 134 operates as an ohmmeter with full-scale ranges from 100 ohms to 10^{14} ohms. The instrument measures resistance by supplying a known constant current to the unknown resistance, and then measuring the resultant voltage across the sample. The constant current output is the reciprocal of the full-scale resistance range utilized. This method of resistance measurement allows a linear presentation, and also allows the instrument to function as a stable general-purpose laboratory current source from 10^{-5} A to 10^{-12} A, variable in decade steps. Further, the Model 134 may be used in the feedback mode for the measurement of very high resistance values, thus eliminating the effects of electrometer and cable capacitances, and giving fast response speeds.

As a coulombmeter, the Model 134 utilizes low-leakage polystyrene capacitors

for accurate charge measurements, and for low-current detection by the rate-of-charge technique. Current detection to better than 5×10^{-16} A is possible, as well as charge measurement to 6×10^{-15} coulomb. The coulombmeter mode allows easy determination of capacitances, materials charge-transfer studies, operation as an integrating voltmeter, and use as a peak-detecting voltmeter-amplifier.

The PAR Model 134, due to its low noise and excellent dc stability, may also be used as a high-quality, low-level, dc amplifier. Further, with an input offset current lower than 3×10^{-15} A, the instrument allows voltage amplification from very high resistance sources. The frequency response for all gains exceeds 1 kHz. The limit of resolution when working from high resistance sources is limited nearly entirely by the Johnson noise of the source resistance. As in the voltmeter mode of operation, the Model 134 may be used as an amplifier in the feedback mode, thus reducing the slowing effects of instrument and shunt cable capacitances.

The MOS input of the Model 134 is fully protected against input overloads to ±600 V, momentary or continuous. The protection circuitry employed allows the user freedom from instrument failure from dc or ac without sacrificing critical input characteristics.

The PAR Model 134 utilizes all virgin-Teflon dielectric materials for excellent performance with regard to moisture and dielectric stressing. High quality aged high-megohm resistors are utilized for excellent performance relative to accuracy, stability, and resistor voltage-coefficient errors.

Featuring a wide range of operating modes and excellent low-level performance, along with ease of operation and reliability through quality component use, superior design, and care in manufacture, the PAR Model 134 Electrometer should be of value in all applications in low-current and high-resistance work, as well as in general-purpose multimeter use.

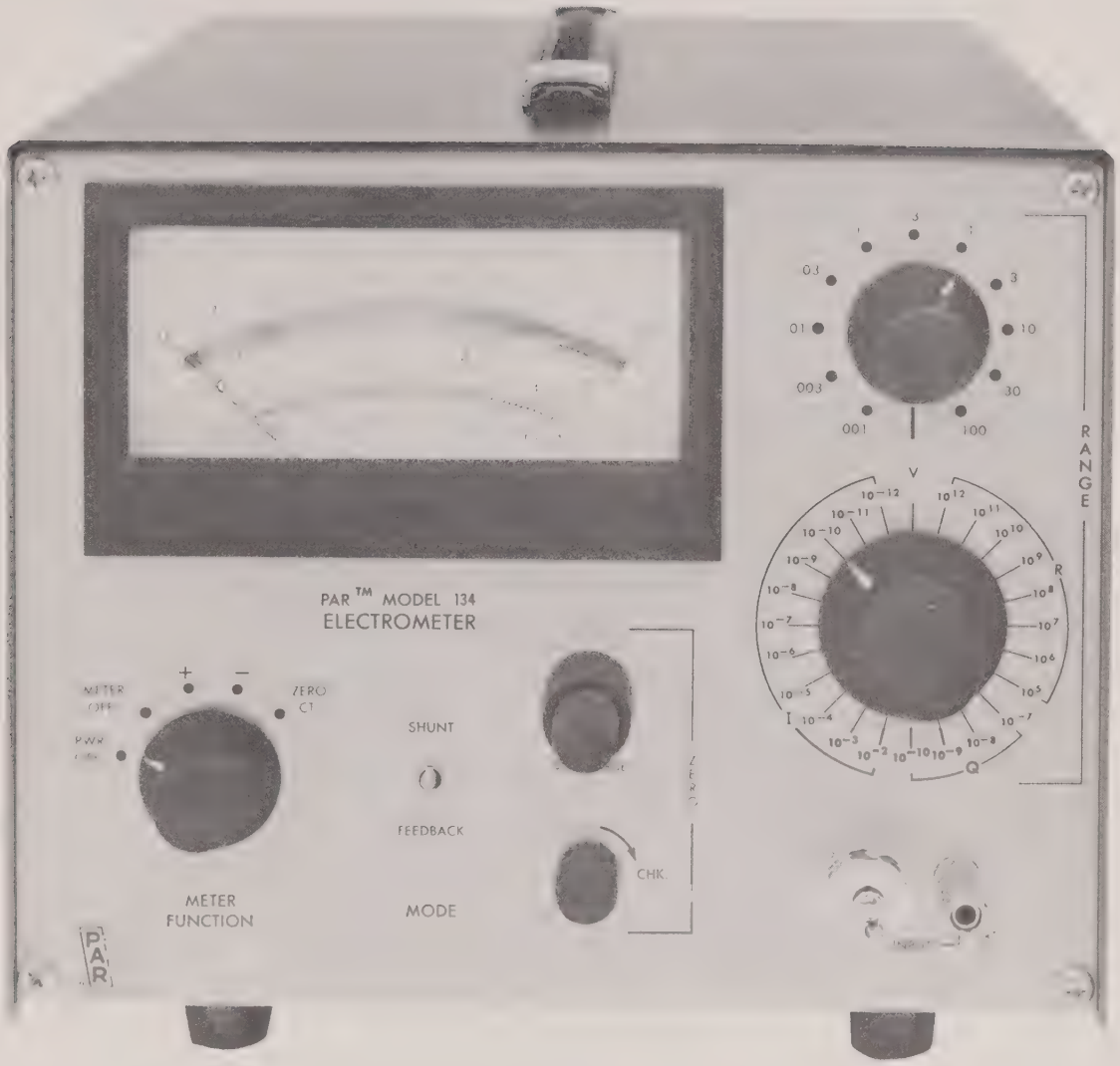


Figure I-1. PAR MODEL 134 ELECTROMETER

1.2 SPECIFICATIONS

VOLTMETER

RANGE: 1 mV to 100 V in 1-3-10 sequence.

ACCURACY: ±1% of full scale on all ranges, exclusive of noise and drift.

STABILITY: Less than 75 μV/°C and less than 500 μV per 24 hour period after 1 hour warm-up.

METER NOISE: 30 μV pk-pk maximum on 1 mV range with the input shorted.

INPUT IMPEDANCE: Greater than 10^{14} ohms shunted by 10 pF. Input resistance is also switch selectable in decade steps from 100 ohms to 10^{12} ohms.

AMMETER - IN PUT RESISTANCE IS RECRICAL OF RANGE SETTING

RANGE: 10^{-14} A to 10^{-1} A full scale in the equivalent of a 1-3-10 sequence through the use of decade range selector and multiplier switches.

ACCURACY: ±2% of full scale on all ranges between 10^{-1} A and 10^{-12} A with the smallest recommended multiplier setting, and ±4% on all other ranges.

CURRENT STABILITY: Less than 10^{-15} A drift per 24 hour period after one hour warm-up.

METER NOISE: 10^{-15} A pk-pk maximum.

OFFSET CURRENT: Less than 3×10^{-15} A.

MAXIMUM RISE TIME (with up to 5000 pF input capacitance):

FULL SCALE RANGE	MAX. RISETIME SECONDS
10^{-14} to 10^{-12}	5.0
10^{-11}	2.0
10^{-10}	0.3
10^{-9}	0.1
10^{-8}	0.03
10^{-7}	0.01
10^{-6} and above	0.003

OHMMETER

RANGE: 100 Ω to 10^{14} Ω full scale in the equivalent of a 1-3-10 sequence through the use of decade range selector and multiplier switches.

ACCURACY: ±3% of full scale on all ranges between 100 ohms and 10^{11} ohms with the largest recommended multiplier setting, and ±5% on all other ranges.

COULOMBMETER

RANGE: 10^{-13} coulomb to 10^{-5} coulomb full scale in the equivalent of a 1-3-10 sequence through the use of decade range selector and multiplier switches.

ACCURACY: ±5% of full scale of all ranges.

STABILITY: Less than 3×10^{-15} coulomb per second drift.

AMPLIFIER

INPUT IMPEDANCE: Greater than 10^{14} ohms shunted by 10 pF. Input resistance can also be switch selected in decade steps from 100 ohms to 10^{12} ohms.

VOLTAGE GAIN: 0.01 to 1000 in 1-3.33-10 sequence through the use of multiplier switch.

GAIN ACCURACY: Better than 0.5%.

FREQUENCY RESPONSE: ±3 dB from dc to 1 kHz on all ranges.

NOISE: Less than 2% rms with gain set to 1000, and less than 0.5% with gains less than 100.

ANALOG OUTPUTS

UNITY GAIN: At dc, output is equal to input within 20 ppm or 50 μV, whichever is greater, exclusive of noise and drift, for all output currents up to 150 μA.

VOLTAGE RECORDER: ±1 V equal to full-scale deflection, inverting. Output resistance is 850 ohms.

CURRENT RECORDER: ±1 mA equal to full-scale deflection, adjustable over range of ±10% for use with 1.4 kΩ recorders.

POWER REQUIREMENT: Switch selectable choice of 90-135 volts or 180-270 volts, 50 to 1000 Hz, single phase. Total power drain is 10 watts.

LINE STABILITY: Less than 10 μV change in reading for a 10% change in line voltage.

CONNECTORS: Teflon insulated UHF Input connector plus binding post ground. Rear panel binding post outputs.

ACCESSORIES SUPPLIED: Input mating connector and a binding post to BNC adapter.

SIZE: 7" H x 8.75" W x 10" D (17.78 cm H x 22.23 cm W x 25.40 cm D).

WEIGHT: 10 lbs. (4.55 kg).

SECTION II
INITIAL CHECKS

2.1 INTRODUCTION

The following procedure is provided to facilitate initial performance checking of the Model 134 Electrometer. In general, this procedure should be carried out after inspecting the instrument for shipping damage (any noted to be immediately reported to the carrier and to Princeton Applied Research Corporation), but before using the instrument experimentally. Should any difficulty be encountered in carrying out these checks, contact the factory or one of its authorized representatives (see list at end of this manual). Locating the controls, switches, etc. may be facilitated by referring to Figures III-2, III-3, and III-4 (pg. III-15 & III-16).

2.2 EQUIPMENT NEEDED

Most of the checks are 'self-checking' in that no special equipment is required to determine that the instrument is functioning properly. The following equipment, however, is recommended to carry out the checkout procedure.

(1) Digital Voltmeter capable of at least 1 mV resolution, and having full-scale voltage ranges of 1 V and 10 V. One suitable voltmeter is the Fairchild Model 7000A.

(2) General-purpose laboratory power supply capable of up to ±15 V output. One suitable voltage source is the Hewlett-Packard Model 6111A.

(3) Coaxial input cable, UHF male to alligator clip; or, banana plug to banana plug test cable.

(4) Output cable, banana plug to banana plug.

2.3 PRELIMINARY STEPS

(1) Check the position of the rear-panel 1 V/1 mA slide switch. Switch must be in the 1 V position.

(2) Check the position of the rear-panel Line Voltage Selector switch. For operation from 115 V ac, '115' should show in the window. For operation from 230 V ac, '230' should show.

(3) Check that the Model 134 Meter Function switch is in the PWR. OFF position. Plug in the line cord.

2.4 PROCEDURE

(1) Set the front-panel controls as follows.

Meter Function	PWR. OFF
Mode	SHUNT
Zero Check	LOCKED (knob rotated to 'depressed' position)

Range ---------- V
Range Multiplier ---------- 1

(2) Turn on the power by rotating the Meter Function switch through all positions to ZERO CT. The meter pointer should advance to center scale (read '0' on 5-0-5 scale).

(3) Zero Controls Check

Connect the digital voltmeter to the Model 134 REC. OUT terminals (rear panel). Increase the Model 134 sensitivity to 10 mV by setting the Range Multiplier switch to .01. Adjust the Coarse and Fine Zero controls as required to set the meter pointer exactly on '0' on the 5-0-5 meter scale.

Adjust the Fine Zero control through its extremes, noting both the digital voltmeter and meter indications. The total Fine Zero span should be in the range of 4 mV minimum to 8.5 mV maximum. Spans between these limits are normal. The digital voltmeter indication should be in the range of 400 mV minimum to 850 mV maximum.

Re-zero the Model 134 meter and output. Decrease the Model 134 sensitivity to 100 mV by setting the Range Multiplier switch to .1. Check the Coarse Zero adjustment by switching the Coarse Zero control through each of its positions, and note the meter reading and digital voltmeter. The meter should read 2.0-2.5 mV per step, and the digital voltmeter should read 20-25 mV per step.

Re-zero the Model 134 meter and output. Decrease the Model 134 sensitivity to 1 V by setting the Range Multiplier switch to 1. Check the rear-panel Zero Range adjustment by switching the Zero Range switch (settable with screwdriver) through each of its positions while observing digital voltmeter and panel meter indications. Both should be in the range of 19-24 mV per step.

NOTE: During the Zero Controls Check, the Model 134 meter may go off scale at the extreme settings of the controls. Should this happen, reduce the Model 134 sensitivity as required with Range Multiplier switch, and note that the voltage at the REC. OUT terminals is always 1 V for full-scale deflection of the panel meter.

(4) Input Voltage Check

Set the Model 134 controls as follows.

Meter Function ---------- +
Mode ---------- SHUNT
Zero Check ---------- LOCKED (knob rotated to 'depressed' position)
Range ---------- V
Range Multiplier ---------- 30

Remove the dust cap from the Model 134 input connector, and connect

the voltage source to the input. Set the Voltage Source to +15 V. Release the Zero Check switch (rotate it so that it's in the 'away from panel' position) and observe that the Model 134 meter indicates 1.5 on the 0-3 scale. The digital voltmeter should indicate -0.5 V at the REC. OUT terminals. Repeat for -15 V input. The polarity of the panel meter and digital voltmeter indications will reverse.

Set the Voltage Source to +3 V and increase the Model 134 full scale sensitivity to 3 V by setting the Range Multiplier switch to 3. The meter should indicate full scale on the 0-3 scale. The digital voltmeter should indicate -1 V. Repeat for an input of -3 V. The polarity of the indications should reverse.

NOTE: The REC. OUT polarity is always opposite the input polarity.

(5) Offset Current

Set the Model 134 controls as follows.

Meter Function	ZERO CT.
Mode	FEEDBACK
Zero Check	LOCKED (knob rotated to 'depressed' position)
Range	10^{-12}
Range Multiplier	1

Replace the Model 134 input dust cap. Increase the sensitivity to .01 and adjust the Zero controls so that the meter reads exactly zero on the 5-0-5 meter scale. Decrease the sensitivity by setting the Range Multiplier to 1.

Release the Zero Check switch. The meter should indicate zero after a small Zero Check release transient. Increase the sensitivity to .01, observing the meter. The offset current should not exceed plus or minus 3 on the 5-0-5 meter scale ($\pm 3 \times 10^{-15}$ A). Full scale is 10^{-14} A, giving $\pm 5 \times 10^{-15}$ A as the sensitivity on the 5-0-5 scale.

NOTE: The offset current may exceed $\pm 3 \times 10^{-15}$ A immediately after stressing the input connector, or if the Model 134 has been on for less than an hour.

This completes the initial checks. If the instrument performed as indicated, one can be reasonably sure that it is functioning properly.

SECTION III
GENERAL OPERATING CONSIDERATIONS

3.1 INTRODUCTION

This section of the manual treats those considerations which apply to electrometer measurement techniques in general, and which are common to all operational modes of the Model 134.

The Model 134 is a multi-function dc instrument and is generally quite simple to operate. However, unlike common multimeters, special considerations apply to the operation and care of the instrument due to its capabilities in the measurement of signals from high-resistance sources and in the measurement of low current levels. Thus, it is recommended that the user acquaint himself with the general operating considerations. In adhering to the basic practices of electrometry, the operator will soon find that use of the Model 134, even at the limits of detection, becomes quite straightforward.

Further, this section also treats the Model 134 controls, basic noise considerations, accuracy, and instrument output considerations.

3.2 PRELIMINARY CONSIDERATIONS

3.2A POWER SWITCHING

Applying power consists of first plugging the line cord into the proper outlet followed by turning on the instrument with the Meter Function switch. Always use the instrument's own power switching (Meter Function switch to PWR. OFF) to turn off the Model 134. It is recommended that the operator not turn off the Model 134 by merely removing the line cord.

3.2B POWER REQUIREMENTS

The Model 134 will accept either 90-135 V ac or 180-270 V ac, 50-1000 Hz. A switch on the rear panel allows the transfer from one operating voltage to the other. For operation from 90-135 Vac, '115' should appear in the window. For operation from 180-270 V ac, '230' should appear.

For operation from 90-135 V ac, a 1/4 ampere, 117 V slow-blow fuse should be installed in the fuseholder at the rear panel. For operation from 180-270 V ac, the fuse should be a 250 V slow-blow fuse rated at 1/8 ampere. The instrument fusing is before and in series with the power switching, the 115-230 switch, and the power transformer primary. When replacing fuses, use only the stated types.

3.2C CABLING

The input connection to the Model 134 may be made in a variety of ways. The instrument input connector is a UHF type, with virgin Teflon insulation, especially selected for properties critical in low-level electrometer measurements.

The recommended methods of connecting to the input follow.

(1) UHF (male) to alligator clip cable, PAR part number 6020-0059-93, or equivalent. Cable may be purchased separately, and is also included in the PAR Model 134/70 Electrometer Connector Kit.

(2) UHF (male) to UHF (male) cable, PAR part number 6020-0058-04, or equivalent. Cable may be purchased separately, and is also included in the PAR Model 134/70 Electrometer Connector Kit.

(3) Banana plug (male) to alligator clip cable, for low impedance general purpose use. Spacing between the Model 134 input connector center terminal and ground binding post is such that standard dual banana plug insertion is possible.

(4) UHF (male) to BNC (female) rigid line, PAR part number 2102-0083-03, enabling rigid low-leakage input connection. May be purchased separately, and is also included in the PAR Model 134/70 Electrometer Connector Kit and in the Model 134/75 Guarded Test Box.

NOTE: The Model 134/70 Electrometer Connector Kit contains an assortment of cables, adapters, and rigid connectors for use with the Model 134 in low-current, high-impedance measurements. Adapters allow use of most common cable types, such as BNC, with the instrument.

3.2D SHIELDING

When operating from high impedance sources, generally above 10^8 ohms, or when measuring low-level currents, generally less than 10^{-8} ampere, or when measuring high values of resistance, namely above 10^8 ohms, always utilize well-shielded sources and input connections. Line-related frequencies will disturb such measurements if poor shielding is present, as the Model 134 frequency response is well above such frequencies.

Further, avoid strong magnetic fields very near the Model 134 when operating under low-level high-impedance conditions. The Model 134 is, however, fairly immune to magnetic field penetration from below the instrument due to its steel bottom plate.

In measuring signals from low-impedance sources (less than 10^8 ohms), unshielded input connections may be employed on most ranges; it is preferable to keep such connections as short as possible.

3.2E GROUNDING

No special grounding requirements are necessary, other than those normally required of all instruments. The Model 134 case is connected to the 'third wire' ground pin on the line cord. However, the instrument can be isolated from power line ground by means of a three to two line adapter plug without performance degradation or shock hazard. When the Model 134 is used off power line ground, floating operation is permissable, but do not exceed 100 V. Avoid shorting out the Model 134 case to power line ground when floating at or near this voltage level.

When using the Model 134 with other line-operated instruments, follow standard grounding practices to avoid ground loops in the measurement set-up. The Model 134 has very low output ripple, and the user may wish to experiment, depending on the application, with line-isolating the signal source, electrometer, and/or recorder or oscilloscope, to eliminate induced ground loops in the system hook-up.

When operating the Model 134 in the FEEDBACK mode, reverse the polarity of the recorder or oscilloscope connection to the electrometer recorder output. This is advisable because internal reference grounds of the Model 134 are changed with Mode switch operation, relative to the output. Symmetry is preserved when reversing the polarity of the output connection. Further, when operating the Model 134 in the FEEDBACK mode, the electrometer case ground (and therefore the source low) must not have a common return (ground) with another instrument at the recorder output. Isolate either the electrometer-source combination or the instrument connected to the Model 134 output from power line ground with a three-to-two adapter plug. No special precautions, other than good grounding practices, need be observed when operating the Model 134 in the SHUNT mode.

3.2F WARM-UP

The Model 134 warm-up period is specified as one hour, relative to operation well within all stated specifications. The warm-up characteristic requirement is common to all electrometers and picoammeters employing MOS devices as the input stage.

Figure III-1 shows a 60 hour typical voltage stability run from a cold start of a production Model 134. Note that, after an initial one-hour warmup period, the voltage drift was well within the specified limit of 500 μV/day. Specifications requiring a warm-up period include voltage stability as a function of time and temperature, offset current, and offset current stability.

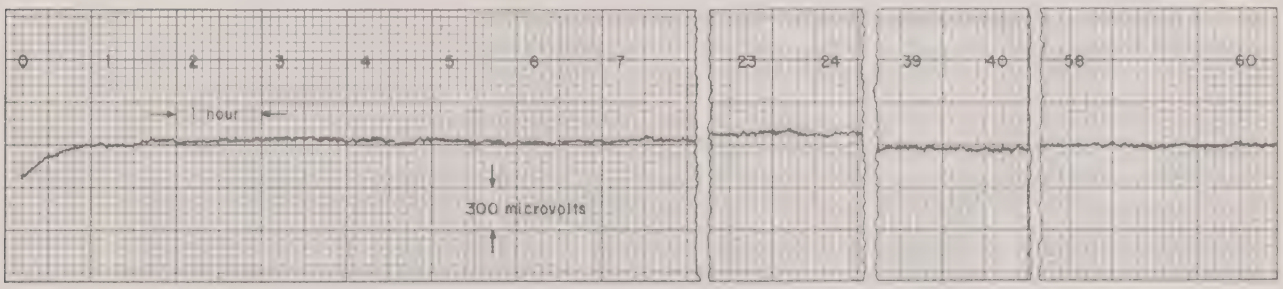


Figure III-1. SIXTY-HOUR VOLTAGE STABILITY RUN FROM COLD START FOR TYPICAL MODEL 134

Typically, the Model 134 will be within stability specifications within the first 30 minutes from a cold start. Normal voltage drift, in the first fif-

teen minutes, will vary from 100 μV to 600 μV. After the initial one hour warmup period, voltage drift will typically be no greater than 50 μV in any given one hour period, and will not exceed 500 μV per 24 hour period. Similarly, the input offset current stability is specified at 10^{-15} A per 24 hours, maximum.

Exposure to cold and damp environments prior to turn-on, very high temperatures (100°F to 125°F), or severe input overloads, may possibly lengthen the typical warmup time of the Model 134.

Voltage and offset current drift are non-cumulative with respect to time. Thus, a specification of 50 μV per hour does not imply a 24 hour drift of 1200 μV. Rather, upon recording a stability run in any given 24 hour period, after a one hour warmup, one will observe the non-cumulative nature of the drift, noting that the maximum drift between any two given 24 hour points will be less than 500 μV.

3.2G MATERIALS

One of the most important factors in the design and application of electrometers is a consideration of the physical characteristics of different materials. A proper choice of insulation material assures ease of operation, repeatability, and accuracy in low-current high-impedance measurements. In selecting insulating materials for electrometer measurements, the following factors must be considered:

(1) Volume resistivity

(2) Water absorption

(3) Surface resistivity

(4) Piezoelectric effects

(5) Triboelectric effects

(6) Fabrication effects

(7) Materials origin

Suitable materials for electrometer measurements include Teflon, Kel-F, polystyrene, polyethylene, and sapphire. Of these, Teflon is generally accepted as the most widely-used and satisfactory, due to its excellent electrical properties, ease of machinability, and low cost. Kel-F is as good as Teflon in most properties, but it is considerably more expensive. In general, most fluorocarbons, such as Teflon and Kel-F, are excellent insulating materials. Both Teflon and Kel-F must be virgin-type, and not reconstituted, for reasons of volume resistivity and piezoelectric effects.

Polystyrene is an excellent material with regard to volume resistivity and low cost, but it easily crazes when machined and water films tend to form across its surface under high humidity conditions.

Polyethylene has good volume resistivity characteristics, depending upon

whether it is of the soft, semi-rigid, or rigid type. It has similar water-filming surface properties to polystyrene, and is not suitable for high temperature work.

Sapphire is considered the near-ideal material for electrometer work, having very high volume resistivity (property is material-purity dependent), extremely low water absorption, good resistance to water filming, very low piezoelectric effect, and low triboelectric properties. The major problems encountered when considering sapphire as a material choice are high cost and difficulty in machining.

Unsuitable materials for electrometry include diallyl phthalate, Lexan, nylon, quartz, Lucite, PVC, polypropylene, ceramics, phenolics, and melamine. These materials suffer from poor performance characteristics in one or more of the stated properties important to electrometer work.

Table III-1 summarizes the recommended electrometer materials and their various properties. Table III-2 summarizes the materials generally considered unsuitable for electrometer work. Accompanying the tables is a glossary of terms applying to the subject of materials, as an aid to the user who may be new to electrometry.

GLOSSARY OF TERMS

1. CRAZING - Flaws and cracking induced in materials as the result of machining. Increases piezoelectric-type effects of insulator materials and results in increased water retention.

2. FLUOROCARBON - That class of thermoplastic organic materials generally exhibiting superior dielectric properties, such as Teflon and Kel-F. Included in this class is Teflon-FEP, also a superior material, commonly known as Teflon tubing.

3. PIEZOELECTRIC EFFECT - Undesirable effect, present to some degree in all insulating materials, of internal charge generation due to mechanical stressing.

4. RECONSTITUTED - Thermoplastic material manufactured through the process of utilizing the same material repeatedly, and not from the original raw materials.

5. THERMOPLASTIC - That class of plastic materials which flow under heat, and, with heat and pressure, may be re-utilized and re-formed into different shapes and sizes.

6. THERMOSETTING - That class of plastic materials which during original manufacturing, sets and hardens. The process is irreversible, and thus does not lend the materials available for reconstitution.

7. TRIBOELECTRIC EFFECT - Undesirable effect of surface charge generation as the result of friction between two insulating materials, or a conductor and an insulator. All known insulating materials exhibit the effect to varying degrees.

COMMON (OR TRADE) NAME	MATERIAL NAME	MATERIAL TYPE	Volume Resistivity (ohm-cm)	Water Absorption (%/24 hr)	Minimal Piezoelectric Characteristics	Minimal Triboelectric Characteristics
TEFLON	Polytetrafluroethylene (PTFE)	Thermoplastic Fluorocarbon	10^{17}-10^{19}	<.005	Poor	Fair
KEL-F	Chlorotrifluoroethylene (CTFE)	Thermoplastic Fluorocarbon	10^{17}-10^{18}	<.001	Good	Poor
REXOLITE, STYRON	Polystyrene	Thermoplastic	10^{17}-10^{20}	.01-.05	Good	Poor
----	Polyethylene	Thermoplastic	10^{15}-10^{17}	<.05	Good	Good
QUARTZ	Silicon Dioxide	Ceramic	10^{14}-10^{17}	Nil	Poor	Fair
SAPPHIRE	Aluminum Oxide	Ceramic	10^{17}-10^{19}	Nil	Excellent	Good

Table III-1. PROPERTIES OF SUITABLE ELECTROMETER MATERIALS

COMMON (OR TRADE) NAME	MATERIAL NAME	MATERIAL TYPE	Volume Resistivity (ohm-cm)	Water Absorption (%/24 hr)	Minimal Piezoelectric Characteristics	Minimal Triboelectric Characteristics
DIALL	Diallyl Phthalate	Thermosetting Plastic	10^{12}-10^{15}	.1-.5	Fair	Fair
LEXAN	Polycarbonate	Thermoplastic	10^{14}-10^{16}	.1-.3	Fair	Poor
NYLON	Polyamide	Thermoplastic	10^{13}-10^{15}	.8-1.5	Poor	Fair
PVC	Polyvinyl Chloride	Thermoplastic	10^{11}-10^{15}	.2-.8	Poor	Fair
LUCITE	Polymethyl Methacrylate	Thermoplastic	10^{13}-10^{16}	.2-.7	Fair	Poor
----	Polypropylene	Thermoplastic	10^{15}-10^{17}	.005-.2	Poor	Poor
MELAMINE	Amino Formaldehyde	Thermosetting Plastic	10^{10}-10^{12}	.1-.5	Fair	Fair

Table III-2. PROPERTIES OF UNSUITABLE ELECTROMETER MATERIALS

8. VIRGIN MATERIAL - Original insulating material manufactured directly from the basic raw materials, and not from existing forms of the same material.

9. VOLUME RESISTIVITY - Property of a material characterized as its ability (or inability) to conduct an electric current through the mass or volume of itself. Measurement results, in ohm-cm, are performed with samples of given dimensions, and the resistance being measured is then converted to ohm-cm.

10. WATER ABSORPTION - That property of a material to absorb water into itself from its surroundings. The property is generally stated in terms of the percentage of its own volume it will absorb in 24 hours of water immersion.

3.3 INPUT CONSIDERATIONS

3.3A OFFSET CURRENT

The Model 134 Electrometer input offset current is extremely low, not exceeding 3×10^{-15} A. Typically, the offset current will be well below this value, and can be read directly on the instrument's panel meter. This low offset current results from the low-leakage MOS device employed as the instrument's input stage, as well as from the special design and internal layout of the Model 134.

Upon turn-on from a cold start, the Model 134 may exhibit higher offset current than specified, occasionally as high as 10^{-14} A. This is normal, as there is a warm-up and stabilization characteristic involved. The offset current is usually well within spec. after about ten minutes.

Low offset current in an electrometer is absolutely essential for maximum accuracy and resolution in low-level current measurements, in operation as a voltmeter from high-resistance sources, in ohmmeter operation when measuring very high resistance values, and in coulombmeter operation.

The Model 134 offset current may be somewhat higher than 3×10^{-15} A after severe handling or stressing of either the input connection or the experimental fixture. This condition may also be present after cleaning the input connector, MOS device, or other internal areas associated with the high-impedance input stage. Further, offset current may be excessive after severe input voltage overloads, and recovery may take several hours, depending upon the overload severity and range in use during the overload. Increased offset current and current instability under these conditions is normal and characteristic of electrometers. Within a reasonable time the offset current and current stability both will return to 'in spec' values. Often repeated zero checking on the less sensitive current ranges, with the Mode switch set to FEEDBACK, will hasten dissipation of accumulated charge effects.

If the Zero Check switch is released when using the Model 134 as a voltmeter with the input open, an advancing up-scale reading will result. This effect is caused by the offset current charging the instrument's input capacitance. Zero checking restores the panel meter to zero.

In voltage measurements from extremely high source resistances, such as the measurement of the voltage across a low-leakage charged capacitor, the Model 134's low offset current is essential, in that it introduces negligible error in the measurement.

In the leakage resistance measurement of high-quality capacitors, namely types such as glass or polystyrene, the user may not observe the voltage decay effect necessary to the measurement if the capacitor leakage current is less than the offset current of the Model 134. This is due to the Model 134 offset current sustaining the voltage across the capacitor due to charging effects. Where this is the case, the measurement may be made using the Model 134 as an ammeter, and, with a voltage source in series with the capacitor being tested, measuring current levels with at least two values of applied test voltage.

3.3B INPUT RESISTANCE

The input resistance of the Model 134 is extremely high, being greater than 10^{14} ohms. This parameter is of extreme importance in electrometer work, so that source loading does not occur in high-resistance measurements.

The Model 134 input resistance is maintained through the use of virgin Teflon insulation throughout the instrument, and by driving the entire amplifier circuitry at the same level as the voltage being measured. The driving voltage is available at the rear panel as the Unity Gain output, and is in phase with and equal to the value of the input signal when operating the Model 134 as a voltmeter, amplifier, or ohmmeter.

The input resistance of the Model 134 may be compromised by contamination and moisture on the input connector, MOS device, or the Teflon insulation of the input circuitry. Maintenance of clean conditions, with reasonable instrument care, suffices in assuring that the Model 134 input resistance remains greater than the minimum specified value of 10^{14} ohms.

3.3C INPUT OVERLOADS

The Model 134 is fully protected from accidental input overloads, whether from ac, steady-state, or transient signals. Application of overloads up to ±600 V will not damage the instrument, as guaranteed by the specifications. Each Model 134 is factory tested to overload immunity at ±750 V. Further, power line application to the input will not damage the instrument.

Full overload protection is maintained without compromising the necessary electrometer input characteristics such as input resistance, dc stability, noise, and offset current.

When operating on the more sensitive ranges, severe input overloads may cause temporary dc instability, increased offset current, and increased noise. Such characteristics are normal, and the instrument will meet specifications after a reasonable length of time. The time required depends on the severity of the overload, the duration of the overload, the full scale range, and the mode of operation. Further, some units may recover faster than others. Typically, recovery may vary from less than twenty minutes to possibly a maximum of two to eight hours.

3.3D INPUT CAPACITANCE

The Model 134 input capacitance is specified as 10 pF maximum. Typical measured input capacitance is less than 7 pF.

When working as a voltage amplifier or voltmeter from a high-resistance source, the slowing effects of both the electrometer input capacitance and the cable capacitance may be eliminated by operating in the FEEDBACK mode. In this mode, the total input shunt capacitance is driven at the same potential as the signal source.

Further, in low-current measurements, the low input capacitance of the Model 134 assures lower noise in the more sensitive regions of measurement.

Examination of the input circuitry of the Model 134 will reveal the extent of the design care with regard to minimizing capacitance in the input circuitry. Short lead lengths are maintained throughout, and the printed circuit boards (mother board and plug-in MOS input card) incorporate guard planes beneath all input circuit elements and wire lengths.

3.3E MOISTURE

Maintenance of as near moisture-free conditions as practical are essential to electrometer performance. All insulation materials are compromised with regard to their dielectric properties by moisture. The input circuitry of the Model 134 is designed to minimize the effects of moisture. Teflon is resistant to water-filming under normal conditions of use, but only if the material surface is clean.

Further, water is of low resistivity relative to the circuit resistances encountered in electrometer design and application. Also, contaminants from the moisture are left behind after moisture evaporation.

Generally, moisture is not a severe problem under normal laboratory conditions. The Model 134 will perform to all specifications in up to 70% relative humidity. At the factory, each instrument is packaged in an air-tight plastic bag with a package of dessicant. When storing the Model 134 for extended periods, or when shipping the instrument, it is recommended that the user pack the instrument in the supplied plastic bag with the dessicant package. After an extended period of time, the dessicant becomes saturated. It may be reactivated by baking at 140°F for at least three hours. Dessicant bags are also available from Princeton Applied Research Corporation. When not in use, store the dessicant bag in an air-tight package or bottle with a screw-on cap to maintain it in an active condition.

3.3F CONTAMINATION

Electrometer materials and connections must be maintained as free as possible from dust, dirt, oil, solder flux, and other contaminants. Residues of these materials, as well as those from chemical contaminants, will compromise the insulation resistance of the best dielectric materials. Further, particulate matter adhering to, or imbedded in, insulation materials may present a problem by maintaining short-term electrical charge build-up.

Under normal and reasonably clean laboratory conditions, the user will find that the Model 134 may remain free of contamination problems for periods up to three to four months without cleaning. Often, depending upon conditions, the instrument may not require cleaning for periods up to six months.

When the Model 134 is not in use, it is recommended that the operator cover the input with the attached dust cap provided on the instrument, thus minimizing contamination of the input connector.

3.3G CLEANING

The user will find that the Model 134 will require periodic cleaning of part or all of its high-impedance circuitry. Generally, it is recommended that cleaning be done only if the user suspects or encounters symptoms associated with contamination. Three such common symptoms are:

(1) Increased input offset current that does not decrease after a reasonable time period.

(2) Measured current noise in excess of the level indicated in the specifications.

(3) High-megohm resistor contamination, giving rise to inaccurate current measurements in the form of low readings, and inaccurate resistance measurements in the form of high readings.

If offset current and/or current noise only are high, clean all critical high-resistance points only. Do not clean the high-megohm resistors. The high-megohm range resistors should not be cleaned unless there is evidence of their contamination.

Use only clean methanol or Freon as the solvent when cleaning the Model 134. The use of clean Q-tips as 'swabs' is recommended. Do not use a Q-tip more than once, as contamination of the solvent and electrometer may result. Always keep the Q-tip well moistened by the solvent. The cleaning operation should be performed gently.

Should salts be suspected, first clean with distilled water, followed by the recommended solvent of either clean methanol or Freon. Never use ordinary tap water in place of distilled water.

After cleaning with methanol, it is recommended that the user dry the cleansed area with dry nitrogen gas. Never use common compressed air, as most sources of compressed or bottled air have sufficient oil content to contaminate the Model 134 circuitry. If a source of dry nitrogen gas is not available, let the area air-dry, keeping the instrument out of dust-ridden areas while drying.

Methanol and Freon will not attack any materials used in the Model 134 high-impedance circuitry. Each will remove the red markings on the high-megohm resistors. This is of no concern, other than the fact that the red paint material must not be left, in flaked condition, to give rise to possible resistor contamination.

When cleaning the high-megohm resistors, keep the Q-tip soaked with solvent. Gently clean the resistor surface with soft strokes. Generally, one or two soft strokes with saturated Q-tips will suffice. Dry as recommended for other areas. DO NOT DRY THE RESISTOR WITH A DRY Q-TIP OR ANY OTHER MATERIAL.

3.3H VIBRATION

In typically encountered electrometer applications, movement and vibration of the Model 134, the cables, and/or the experimental set-up will give rise to erratic meter indications and electrometer output signal variations. Such erratic behavior results from one or more of the following effects:

(1) Microphonic effects

(2) Triboelectric effects

(3) Capacitance variations

(4) Piezoelectric effects

Many components, for example high-megohm resistors, exhibit microphonic properties when subjected to vibration. This is due in part to changes in capacitance within the resistor as the element moves. Other examples are electrometer tubes and high-resistance, thin-film, passive components. Such microphonic activity gives rise to spurious sinusoidal-type electrical signals.

One material sliding over another gives rise to spurious electrical charge generation known as the triboelectric effect. A common example is cable movement. Such activity occurs when a conductor slides against an insulator in common cables, specifically when the cable shield braid moves over the dielectric. Erratic signal potentials are thus induced on the center conductor. Cable designed for low-noise operation uses low-loss polyethylene dielectric material, and a powdered graphite coating between the insulation and braid material. The result is charge equalization and minimizing of the undesirable effect. However, movement of even low-noise cable creates erratic signals easily detected by the Model 134.

If a conductor moves in either the electrical set-up or in the electrometer, capacitance changes result. The movement of a conductor through stray fields gives rise to random activity observable on the Model 134 meter and output. The solution is to rigidly tie down all cables, the experiment, and even the electrometer. Isolation of nearby fans, motors, and other sources of vibration is helpful. Avoid physical jarring of the experimental set-up by the operator. Internal inspection of the Model 134 will reveal care in the design to eliminate any internal component and wire movement. Short heavy wire lengths are essential, along with rigid internal mechanical support.

In either the set-up or cabling, movement may give rise to charge generation in insulator materials such as Teflon due to the piezoelectric effect. All dielectric materials suitable for electrometer work exhibit the piezoelectric effect to some degree, even low-loss polyethylene and sapphire. Again, the solution is to restrict movement and avoid sharp jarring of the experiment.

3.3I TEMPERATURE

In low-level current measurements, as well as in voltage measurements from high-resistance sources, errors will be observed due to changes in either the ambient temperature or in the temperature of the experiment. Some sources of temperature-induced errors and/or signals are:

(1) Electrometer temperature coefficient

(2) Temperature-induced stress conditions in dielectrics

(3) Temperature coefficient of parameters or devices being measured, i.e., semiconductor junctions and high-megohm resistors

The Model 134 has a voltage temperature coefficient not exceeding 75 μV/°C. This is caused by the MOS input device offset voltage variation with temperature. For critical applications requiring less drift, Model 134's are available from P.A.R. having a specified temperature stability of 35 μV/°C (modification 134/96). The improved stability results from rigid selection of the input device and certification of the actual temperature stability.

The Model 134 also exhibits errors due to the temperature coefficient of the high-megohm resistors used in the ammeter mode of operation. The resistors are selected to minimize this condition, but observable drift is unavoidable. Further, there may be indication of input offset current variations with temperature. The actual offset current variation with temperature of the input MOS device is not observable, but appears to be so due to a combination of offset voltage and protective device circuitry variations with temperature. This effect can be measured by simply observing the offset voltage temperature coefficient with a zero-checked input, and then repeating with an open (shielded) input on the 10^{-14} A current range. Subtraction of the two measurement results gives the 'apparent offset current temperature coefficient'.

When performing measurements at elevated or cryogenic ambient temperatures, dielectric materials exhibit charge generation, and, at high temperature, often excessive leakage. Further, polyethylene cables will deteriorate at elevated temperatures. Always use Teflon-insulated cables, and Teflon, Kel-F, or sapphire insulators in the experimental set-up. Further, at cryogenic temperatures, dielectric materials exhibit charge generation due to the piezoelectric effect. Material movement with temperature is the cause, resulting in either random signal generation or 'fixed' charge-induced signal outputs. Teflon is poor with regard to this effect. Kel-F is better, with sapphire being best.

Often one encounters a temperature coefficient in the device being measured, or possibly this is the parameter being studied. If the effect is an undesirable one, it must simply be accounted for in the experiment. Offset errors can often be corrected by means of the Model 134 zero controls, or by nulling out the errors externally.

3.4 MODEL 134 CONTROLS

3.4A FRONT PANEL CONTROLS

The following table describes the Model 134 front panel controls and inputs. To identify them physically and schematically, refer to Figure III-2 on page III-15, and to the Schematic Diagrams in Section IX.

CONTROL	FUNCTION	SCHEMATIC REFERENCE
(1) METER FUNCTION	Turns the power on or off, allows the meter to be turned off; selects the meter polarity, and allows center-zero operation of the meter for null-detector use. Polarity affects meter only.	S301
(2) MODE SWITCH	Selects feedback within instrument. SHUNT places range resistors or capacitors across input. FEEDBACK places them in the amplifier feedback loop for improved response speed.	S302
(3) COARSE/FINE ZERO	Allows zeroing of the meter and output by input voltage suppression. Coarse steps are approximately 2.0 to 2.5 mV/step (11 positions) and fine zero is a 10-turn potentiometer with a total span in the range of 4 to 8.5 mV.	S303/ R313
(4) ZERO CHECK	Directly below zero controls, this switch allows user to zero the meter and recorder output. Source sees 10 MΩ to case ground when zero check is depressed momentarily or locked (rotated to position where it is held 'close to panel').	S304
(5) RANGE MULTIPLIER	Selects full-scale voltage range when Range switch is set to VOLTS. Functions as a multiplier (.001 to 100) when measuring current (I), charge (Q), or resistance (R). When Range switch is set to VOLTS, amplifier voltage gain is the reciprocal of the range multiplier setting (X1000 to X.01).	S305
(6) RANGE SWITCH	Selects instrument function as voltmeter (V), ammeter (I), coulombmeter (Q), or ohmmeter (R). With Mode switch in SHUNT position, input resistance is selectable from 10^{12} to 100 ohms by appropriate I settings. Thus, unit can either be used as a shunt ammeter or as a voltmeter with variable input resistance. In the volts position (V), the input resistance as an amplifier or voltmeter is greater than 10^{14} ohms.	S306

(7) INPUT CONNECTOR	Virgin Teflon-insulated UHF type. Allows shielded rigid input connection and low input capacitance.	----
(8) CASE BINDING POST	Allows ground connection with standard banana plug.	----

3.4B REAR PANEL CONTROLS

The following table describes the Model 134 rear panel controls and outputs. To identify them physically and schematically, refer to Figure III-3 on page III-15, and to the Schematic Diagrams in Section IX.

CONTROL	FUNCTION	SCHEMATIC REFERENCE
(1) ZERO RANGE	Ten-position switch allows added zero or input suppression, 19-24 mV/step.	S307
(2) 1 V/1 mA SWITCH	Selects full-scale recorder output of 1 V or 1 mA corresponding to full-scale meter deflection.	S309
(3) 1 mA ADJ.	Allows 10% variation in 1 mA output when 1 V/1 mA switch is set to 1 mA position.	R326
(4) UNITY GAIN OUTPUT	Provides accurate X1 output corresponding to input. Output resistance is such that 150 μA may be drawn on any range.	----
(5) GUARD	Provides for guarded measurements when making fast voltage or resistance measurements. Also serves as unity-gain output when mode switch is in the FEEDBACK position.	----
(6) RECORDER OUTPUT	High (red) and low (blue) output for voltage or current recorders. Also provides true constant current (1 V/1 mA switch in 1 mA position) of up to 1 mA as read on panel meter.	----

3.4C INTERNAL CONTROLS

The following table describes the Model 134 internal controls. To identify them physically and schematically, refer to Figure III-4 on page III-16 and to the Schematic Diagrams in Section IX.

CONTROL	FUNCTION	SCHEMATIC REFERENCE
(1) R-CAL.	Ohmmeter calibration.	R219

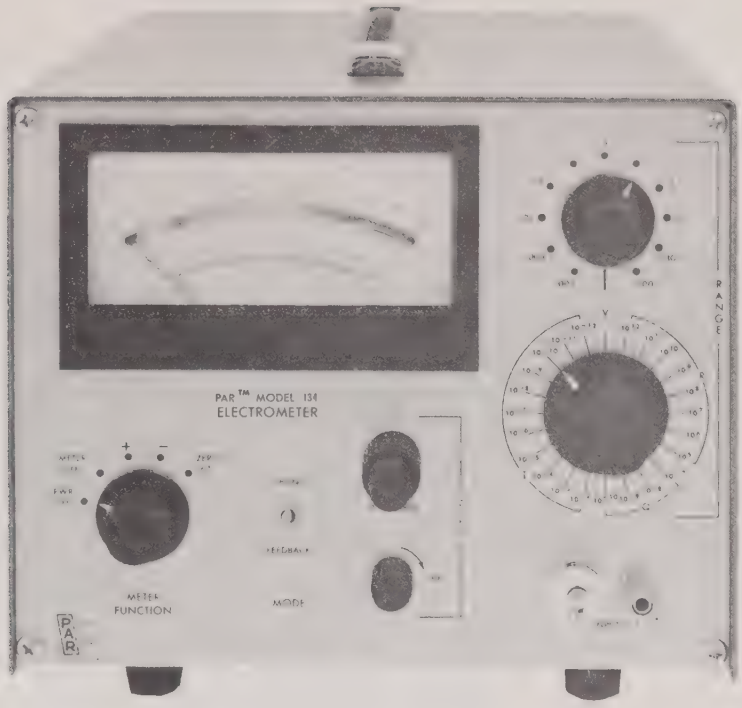


Figure III-2. FRONT VIEW OF MODEL 134 ELECTROMETER

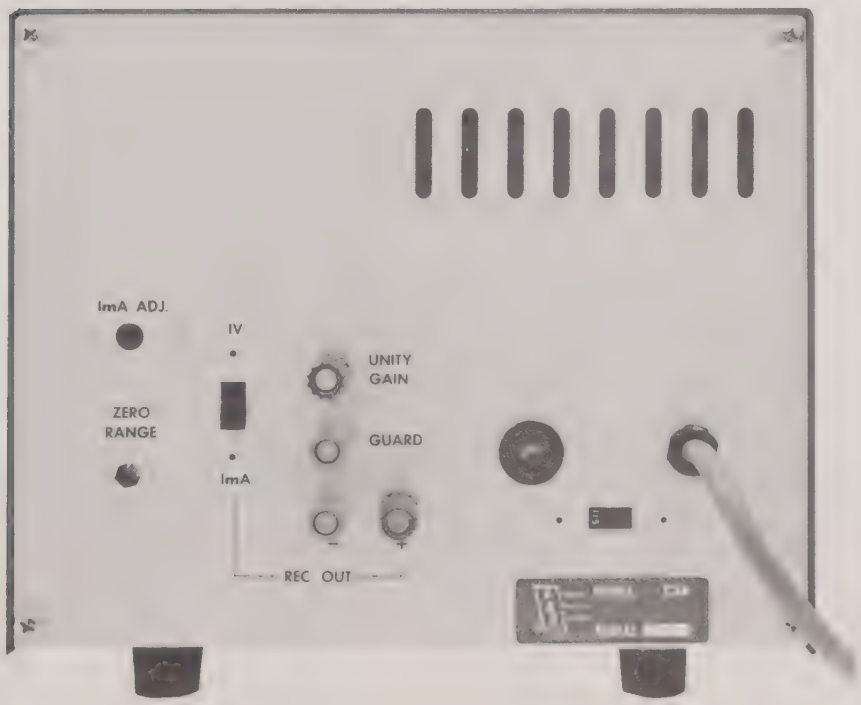


Figure III-3. REAR VIEW OF MODEL 134 ELECTROMETER

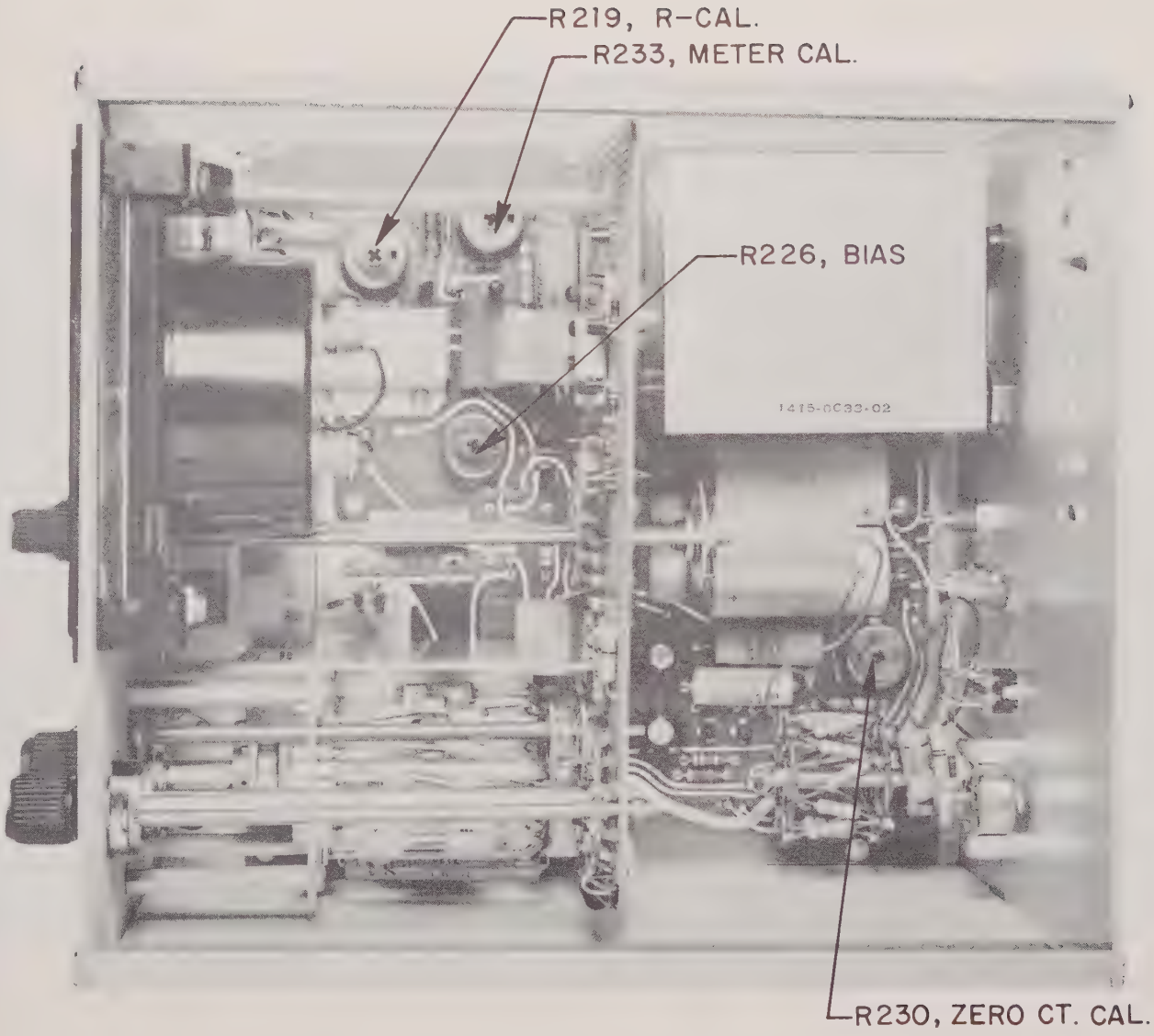


Figure III-4. MODEL 134 INTERNAL CONTROLS

(2) BIAS	Adjusts output idling current and crossover distortion.	R226
(3) ZERO CT. CAL.	Calibrates center zero (meter).	R230
(4) METER CAL.	Calibrates full-scale meter deflection.	R233

3.5 NOISE CONSIDERATIONS

3.5A INTRODUCTION

In addition to cable noise effects, piezoelectric disturbances, vibration, and temperature and time-dependent stability, all of which may be referred to as noise in that they tend to limit resolution and impair measurement accuracy, there are three additional types of noise which must be dealt with. They are Johnson noise, often referred to as 'white' noise, shot noise, and flicker noise (1/f).

In the design of a practical electrometer, in conducting an experiment, and in using an electrometer, each noise type may be significant and generally cannot be totally ignored. A basic understanding of noise types, their origin, and the role each plays in measurements will be valuable to the operator in terms of measurement ease and success.

The noise voltage of the Model 134 is entirely due to that of the input MOS device. Figure III-5 is an example of actual measured noise, in $\mu V/\sqrt{Hz}$, as a function of frequency. The flicker and Johnson noise regions are very distinguishable.

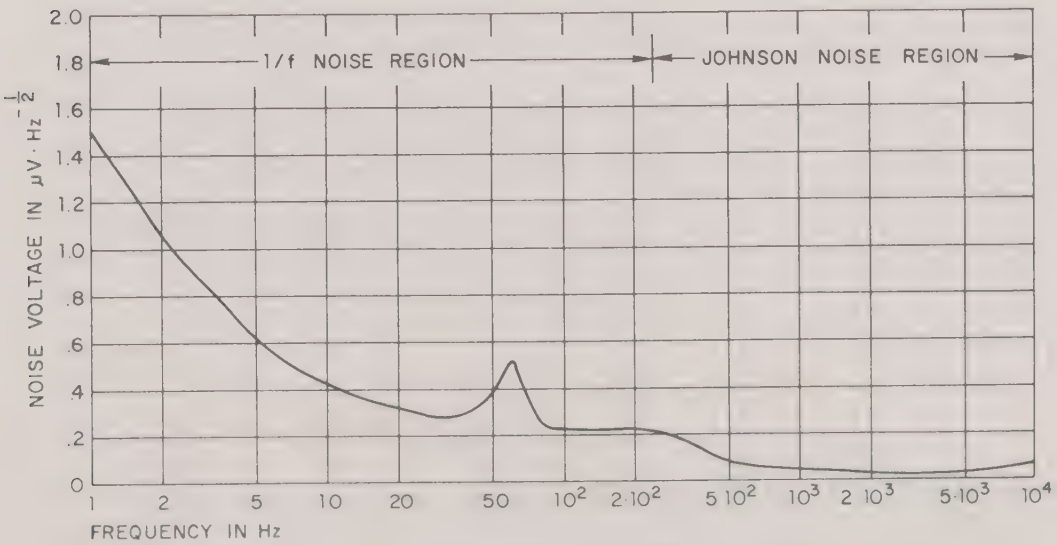


Figure III-5. NOISE VOLTAGE OF TYPICAL MODEL 134

3.5B JOHNSON NOISE

Often referred to as white or thermal noise, Johnson noise is the result of

random charge variations present in all conductors. It is directly proportional to the square root of absolute temperature and resistance, its value being given by:

$$e_n = (4KTRf)^{\frac{1}{2}} \qquad \text{(Equation 1)}$$

where e_n = rms noise voltage
K = Boltzmann's constant, 1.38×10^{-23} joules per kelvin
T = temperature in kelvins
R = resistance in ohms
f = noise bandwidth, or 1.57 times the signal bandwidth

In an ideal voltage measurement, the resolution will be limited solely by the Johnson noise of the source resistance. Lowering the temperature of the source, lowering the possible source resistance, or decreasing the noise bandwidth, will all result in improved signal-to-noise ratio, assuming the Johnson noise of the source is the only significant noise contributor present in the measurement.

In a current measurement, the input produces a voltage across a high-megohm shunt or feedback resistor. This voltage is directly proportional to the current being measured. Increasing the shunt or feedback resistor value reduces the Johnson current noise and improves the resolution because the signal level increases directly with the resistance, while the noise voltage varies as the square root of the resistance. Thus, by simple application of Ohm's Law, we have

$$\overline{i}_n = 2(KTf/R)^{\frac{1}{2}} \qquad \text{(Equation 2)}$$

In the ammeter case, using the highest possible shunt or feedback resistor will result in the best signal-to-noise ratio, assuming the Johnson noise of the ammeter is the only significant noise contributor present in the measurement.

Active circuit elements such as bipolar transistors, junction field effect devices, and MOS field-effect transistors also exhibit Johnson noise characteristics. The noise mechanisms are somewhat more complex than these of resistors, but it is definitely inversely proportional to the transconductance of the device. An example might be a well-characterized junction field-effect geometry, where the Johnson noise resistance is approximately

$$R_n = \frac{0.55 - 0.65}{gm} \qquad \text{(Equation 3)}$$

where gm = device transconductance

As with resistors, the noise is of course 'white' in nature, i.e., constant power per unit bandwidth.

3.5C SHOT NOISE

Current flow through a semiconductor junction gives rise to a current noise component, often expressed in amperes per root hertz, and known as shot noise. Its value is given by:

$$\overline{i_n} = (2eI_{dc}f)^{\frac{1}{2}} \qquad \text{(Equation 4)}$$

where $\overline{i_n}$ = rms shot noise
e = electronic charge, 1.6×10^{-19} coul
I_{dc} = current in amperes

Shot noise, like Johnson noise, is 'white' in nature, and is a characteristic of all semiconductor devices and electron tubes. Thus, a junction field-effect transistor having a gate current of one picoampere is limited to a current resolution of 2.8×10^{-15} A (assuming a 1 Hz noise bandwidth), this being the peak-to-peak value of the shot noise.

MOS electrometer input devices, because they have a finite input gate offset current, also exhibit shot noise. However, effects of the shot noise component cannot be seen, as the gate current of the device is very minute. Here we are discussing the actual MOS device current component, exclusive of device header leakage current, which, in fact, is the major contributor to input offset current observed. The header leakage current does not give rise to shot noise.

3.5D FLICKER (1/f) NOISE

Flicker noise, although not as well understood as Johnson and shot noise, is observed in all thermionic and semiconductor devices. The effect is also present in high-megohm resistors carrying current. The phenomenon is characterized by a noise power which varies inversely with frequency.

In active circuit elements, such as MOS devices, the effect results from the device being a surface-controlled amplifying device. Also, the effect is highly dependent on the geometry of the device, the doping of the device channel and junctions, and the quality of the passivation and gate oxide layers. In MOS devices, flicker noise is also temperature dependent to a fair degree, decreasing in well-defined geometries with decreasing temperature, until the mobility peak of silicon is reached.

Further, high-megohm resistors often exhibit flicker-type noise when carrying current. The effect is believed to result from charge-trapping centers being randomly generated and filled within the conductive surface of the element. However, in practical electrometers, and with high-quality resistors, the effects of this noise mechanism are considerably lower than the resistor's Johnson noise.

3.6 ACCURACY CONSIDERATIONS

Often the ammeter or ohmmeter accuracy specification of an electrometer contains such statements as 'optimum multiplier setting' or 'smallest recommended multiplier setting'. In doing current or resistance measurements, for best accuracy it is advisable to utilize as large a Range Multiplier switch setting as possible. Thus, with the Model 134, it is necessary to specify some minimum value of Range Multiplier setting to define the worst-case accuracy, which is determined by the following factors:

(1) High-megohm resistor tolerance

(2) Error due to amplifier loop gain, which becomes lower with smaller Range Multiplier settings

(3) Error contribution of noise and drift on lower Range Multiplier settings

(4) Tolerance of Range Multiplier resistors, which determine electrometer voltage accuracy (±0.1% for all resistors in the Model 134)

(5) Error due to high-megohm resistor noise

Thus, the 'smallest recommended multiplier setting' in the Model 134 has been verified to be the .01 setting. The user can also verify this through extensive error-limit studies with the instrument.

When the 'optimum recommended multiplier setting' is stated, it may often mean the use of the largest multiplier setting. Other PAR electrometers use this statement, and it is defined as the two lowest Range Multiplier settings available.

3.7 OUTPUT CONSIDERATIONS

3.7A RECORDER OUTPUT

To facilitate operation with chart recorders, oscilloscopes, and other instrumentation, the Model 134 is provided with a recorder output (REC. OUT) that is switch-selectable for voltage or current output. Two terminals, a red and a blue, positive and negative respectively, are provided at the rear panel.

With the rear panel 1 V/1 mA switch set to 1 V, full scale on the panel meter is represented at the output as one volt. The voltage gain of the Model 134 is the reciprocal of the Range Multiplier switch setting. The frequency response on all ranges is specified as 1 kHz minimum, and the recorder output is accurate at dc to better than ±0.5% of full scale. The output resistance of the voltage recorder output is 850 ohms ±0.1%. The recorder output is short-circuit proof, and will not supply more than 3 mA into a short circuit. Further, although the specified output is one volt, the output will deliver better than two volts while maintaining the stated accuracy and frequency response.

NOTE: WHEN THE MODE SWITCH IS IN THE SHUNT POSITION, REC. OUT (-) IS COMMON WITH CASE GROUND (INPUT LOW). WHEN THE MODE SWITCH IS IN THE FEEDBACK POSITION, ISOLATE THE RECORDER FROM THE MODEL 134 CASE GROUND.

The recorder output exhibits very low ripple. When the Mode switch is set to SHUNT, connect the recorder terminals directly to REC. OUT (+) and (-). Reverse the recorder input for FEEDBACK mode operation to maintain lowest output ripple.

The recorder output polarity is opposite the polarity of the input signal and meter indication. Further, the meter accuracy is not affected by shorting the recorder output with the 1 V/1 mA switch set to 1 V.

CAUTION: DO NOT APPLY THE LINE VOLTAGE OR EXTERNAL VOLTAGES OF ANY TYPE TO THE REC. OUT TERMINALS AT ANY TIME, AS THE OUTPUT IS NOT PROTECTED FROM EXTERNAL VOLTAGE APPLICATION.

With the 1 V/1 mA switch set to 1 mA, the Model 134 will deliver 1 mA for a full scale input on all ranges. The 1 mA output is adjustable over a 10% range for exact recorder calibration. The 1 mA output is designed for use with 1400 ohm recorders. The frequency response and output dynamic range are the same as for 1 V operation. When operating with the 1 mA output, load the REC. OUT at all times. An open circuit will cause errors in the meter readings. As with 1 V operation, observe the recorder output precautions with regard to the recorder and setting the Mode switch.

3.7B UNITY GAIN OUTPUT

The Model 134 has a rear-panel UNITY GAIN output for use in buffer amplifier applications and for precise duplication of an input signal level. The red terminal is positive, or high, and the GUARD terminal is negative, or low.

The UNITY GAIN output is non-inverting relative to the input and corresponds exactly to the meter reading and input signal. The accuracy is specified to be 20 ppm of the input or better, and typically is better than 5 ppm. The frequency response, although not specified, is at least as good as that of the recorder output. Both the UNITY GAIN output and the recorder output may be used simultaneously.

The output resistance of the UNITY GAIN output is the value of the Range Multiplier resistor used on any given Range Multiplier switch setting. Thus, for a Range Multiplier switch setting of .01, the UNITY GAIN output resistance is 8.5 ohms, and, at 100, the output resistance is 85 kΩ. The output resistance follows the Range Multiplier settings in 1-3-10 sequence. Further, up to 150 μA may be drawn from the UNITY GAIN output on all ranges.

The UNITY GAIN output is short-circuit proof on all ranges, and will not supply more than 3 mA into a short circuit.

CAUTION: DO NOT APPLY THE LINE VOLTAGE OR EXTERNAL VOLTAGES OF ANY TYPE TO THE UNITY GAIN OUTPUT AT ANY TIME, AS THE OUTPUT IS NOT PROTECTED FROM EXTERNAL VOLTAGE APPLICATION.

The Model 134 may be used with a grounded recorder attached to the UNITY GAIN output, while operating in the FEEDBACK mode, simply by connecting the recorder low to the UNITY GAIN output (red) and the recorder high to the GUARD terminal (blue).

3.7C GUARD

The GUARD terminal on the Model 134 rear panel serves as a means of connecting the signal source low when making guarded, feedback voltage, or resistance measurements.

The GUARD terminal is common within 10 ohms with the REC. OUT (-). They may be used interchangeably if desired.

GUARD also serves as the UNITY GAIN output with the Mode switch set to FEEDBACK. Do not make a common path between the Model 134 case and GUARD when in the FEEDBACK mode.

SECTION IV
SPECIFIC OPERATING INSTRUCTIONS

4.1 INTRODUCTION

The PAR Model 134 Electrometer, although a highly sensitive and sophisticated multifunction instrument, is basically quite simple to operate. The user will find that, with familiarity, voltage, current, charge, and resistance measurements can be easily made, even at the extremes of sensitivity. However, before using the instrument for measurement purposes, the operator is advised to first read Section III, the GENERAL OPERATING CONSIDERATIONS. This is particularly true if the operator is generally unfamiliar with electrometry and low-level measurement techniques. Also, it is advisable to read this section of the manual in sequence.

4.2 CONDENSED OPERATING INSTRUCTIONS

The following table constitutes a short-form operating guide for the Model 134. This table should serve as a handy 'refresher' if the instrument has

MEASUREMENT	TYPE	SOURCE CONNECTION		MODE SWITCH	RANGE SWITCH	CONSIDERATIONS
		HIGH	LOW			
VOLTAGE	Conventional, Shunt, or "Normal"	HIGH (center pin of input UHF)	UHF shell or case binding post	SHUNT	V	Generally for low source resistance voltage measurement, to 10^9 ohms. Input resistance is variable with Range switch. Input resistance is greater than 10^{14} ohms with Range switch set at V.
	Guarded, Feedback, or "Fast"	HIGH (center pin of input UHF)	GUARD binding post	FEEDBACK	V	Generally for high source resistance voltage measurement, to greater than 10^{14} ohms, where fast response speed is desired and errors due to cable leakage are eliminated. Input resistance is greater than 10^{14} ohms with Range switch set at V, and is variable with Range switch.
CURRENT	Conventional, Shunt, or "Normal"	HIGH (center pin of input UHF)	UHF shell or case binding post	SHUNT	(I), 10^{-2} to 10^{-12}	Generally for higher current levels, and when current source resistance is at least 100 times electrometer shunt resistor (reciprocal of Range switch setting). Also, for low currents when damping is desired.
	Feedback or "Fast"	HIGH (center pin of input UHF)	UHF shell or case binding post	FEEDBACK	(I), 10^{-5} to 10^{-14}	Generally for lower current levels where fast response speed is desired, and errors due to finite current source resistance and input connection leakage paths are minimized.
RESISTANCE	Conventional, Shunt, or "Normal"	HIGH (center pin of input UHF)	UHF shell or case binding post	SHUNT	(R), 10^5 to 10^{14}	Generally for measurement of low resistance, to 10^{11} ohms.
	Guarded, Feedback, or "Fast"	HIGH (center pin of input UHF)	GUARD binding post	FEEDBACK	(R), 10^5 to 10^{14}	Generally for measurement of high resistance, to 10^{14} ohms, and when fast response speed and freedom from input connection leakage resistance is required.
CHARGE	Conventional, Shunt, or "Normal"	HIGH (center pin of input UHF)	UHF shell or case binding post	SHUNT	(Q), 10^{-7} to 10^{-14}	For charge measurements from very high or "near ideal" output resistance sources. Also, for voltage measurement where long time constant is desired for damping. Useful for capacitance measurements.
	Feedback or "Fast"	HIGH (center pin of input UHF)	UHF shell or case binding post	FEEDBACK	(Q), 10^{-7} to 10^{-10}	For charge measurements where true linear measurement is required, and where output resistance of source may be either unknown or considerably lower than "ideal".
NOTE: WHEN OPERATING THE MODEL 134 IN THE FEEDBACK MODE, THERE MUST NOT EXIST A COMMON GROUND BETWEEN THE ELECTROMETER-SOURCE AND THE LOW OF THE RECORDER OUTPUT (REC. OUT "-"). FLOAT THE ELECTROMETER-SOURCE, ISOLATE THE RECORDING DEVICE FROM POWERLINE GROUND, OR USE THE UNITY-GAIN OUTPUT AS RECORDER LOW.						

Table IV-1. CONDENSED OPERATING INSTRUCTIONS

not been used in some time, or as a practical guide for getting the instrument into use in the shortest possible time. However, the operator should realize that many considerations germane to making consistently valid measurements at the extremes of sensitivity must necessarily be glossed over in a table. For this reason, the operator is strongly advised to read the remainder of this section and also Section III before proceeding to use the instrument for critical measurements.

4.3 INTERNAL FUNCTIONING

Before proceeding to the detailed operating instructions, it may be helpful for the user to gain a basic understanding of the internal functioning of the Model 134, and of how the source being measured connects to the instrument. Figure IV-1, a basic block diagram of the instrument, is provided as a reference for the following discussions, as are Figures IV-2, IV-3, IV-5, IV-6, and IV-7, block diagrams of the instrument in each of its major operating modes.

Referring to Figure IV-1, note that the Range switch selects one of the four operational functions plus range. The Zero Check switch, S304, allows the instrument to be zeroed on any range or function. The Mode switch selects the internal feedback.

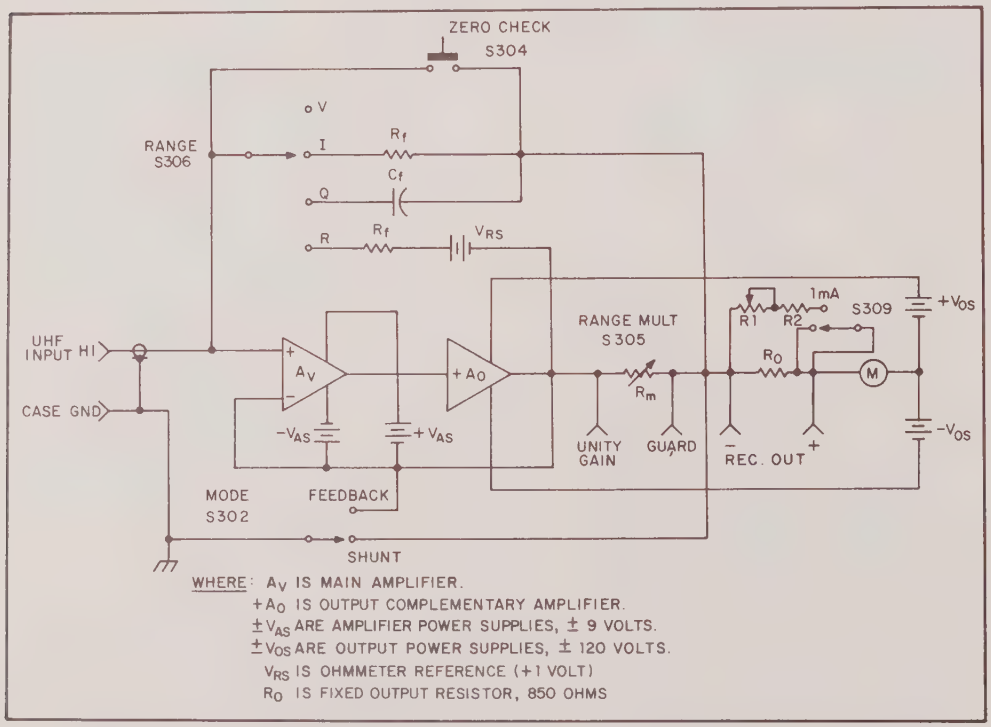


Figure IV-1. BASIC BLOCK DIAGRAM OF THE MODEL 134

Depending on the position of the Range switch, R_f can take values from 100

ohms to 10^{12} ohms, corresponding to current ranges of 10^{-2} to 10^{-12} ampere. The same resistors are used in ohmmeter operation, but with the range in ohmmeter operation extending from 10^{5} ohms to 10^{12} ohms. In charge measurements, C_f is 'in' the circuit, and the allowable range extends from 10^{-7} F to 10^{-10} F in decade steps, corresponding to 10^{-7} to 10^{-10} coulomb.

The Range Multiplier resistor selected by S305 determines the voltage range and/or the Range Switch multiplier. Further, the output resistance of the Unity Gain Output, taken from UNITY GAIN and GUARD, varies with the setting of the Range Multiplier switch.

With S309 set to 1 V, the fixed output resistor, R_o, is 850 ohms, and the closed-loop voltage gain of the instrument is simply this output resistance divided by the selected value of R_m. The open-loop voltage gain of the Model 134 is 500,000 minimum, and high values of feedback are maintained on all ranges. Table IV-2 gives the Range Multiplier settings and other important system characteristics.

RANGE MULTIPLIER SETTING	FULL-SCALE VOLTAGE SENSITIVITY	CLOSED-LOOP VOLTAGE GAIN	MINIMUM FEEDBACK FACTOR	UNITY GAIN OUTPUT RESISTANCE (OHMS)
.001	1 mV	1000	500	.85
.003	3 mV	333	1500	2.55
.01	10 mV	100	5 k	8.50
.03	30 mV	33.3	15 k	25.5
.1	100 mV	10	50 k	85.0
.3	300 mV	3.33	150 k	255
1	1 V	1	500 k	850
3	3 V	.333	"	2.55 k
10	10 V	.1	"	8.50 k
30	30 V	.033	"	25.5 k
100	100 V	.01	"	85.0 k

Table IV-2. INSTRUMENT PARAMETERS AS A FUNCTION OF RANGE MULTIPLIER SETTING

With S309 set to 1 mA, the Model 134 output is 1 mA for full-scale meter deflection. As can be seen from Figure IV-1, R_o is replaced by the output load in parallel with R1 and R2, and the load current can be set by R1, the 1 mA ADJ control.

4.4 VOLTAGE MEASUREMENT

4.4A SHUNT METHOD

The shunt method, often referred to as the 'conventional' or 'normal' method, is the most common way of making voltage measurements. Figure IV-2 shows the instrument configuration for this method. As can be seen, the input connection is made to the Input UHF connector. The following series of steps outlines the shunt method of making voltage measurements.

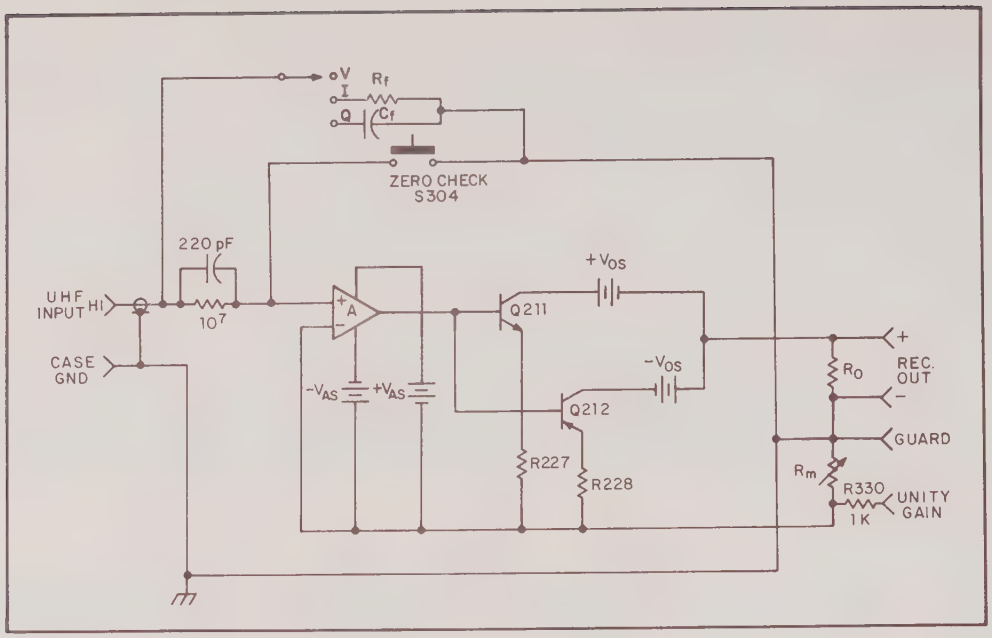


Figure IV-2. FUNCTIONAL DIAGRAM FOR SHUNT VOLTAGE, SHUNT CURRENT AND SHUNT CHARGE MEASUREMENT

(1) Set the controls as follows.

Range switch	V
Range Multiplier	100
Meter Function	ZERO CT
Zero Check	LOCKED
Mode switch	SHUNT

(2) Connect the electrometer to the source voltage (Figure IV-2), unlock the Zero Check switch, and increase the sensitivity as required to obtain an on-scale reading.

(3) If desired, set the Meter switch to '+' or '-', as appropriate, to obtain an 'end-zero' meter reading.

(4) On the more sensitive ranges, recheck and, if required, readjust the zero by depressing or locking the Zero Check switch and using the front panel Zero controls.

Source voltages up to the maximum range of the electrometer's Zero controls (Zero Range, Coarse Zero, and Fine Zero, all added together), approximately 220 mV, may be offset without sacrificing input dynamic range. The zero stability of the instrument is such that small variations around this offset can be seen without degrading the unit's specifications.

Note that, in SHUNT operation, the Model 134 case ground (circuit low) is in common with the rear-panel GUARD and REC. OUT (-) terminals.

When zeroing, that is, with the Zero Check switch depressed, the voltage source will see 10 MΩ to circuit low. Whenever the Zero Check switch is not depressed, and providing the Range switch is set to 'V', the input resistance is greater than 10^{14} ohms. Lower input resistances can be obtained by selecting any of the current (I) ranges from 10^{-2} A to 10^{-12} A, in which the input resistance is the reciprocal of the selected current range, or 100 ohms to 10^{12} ohms.

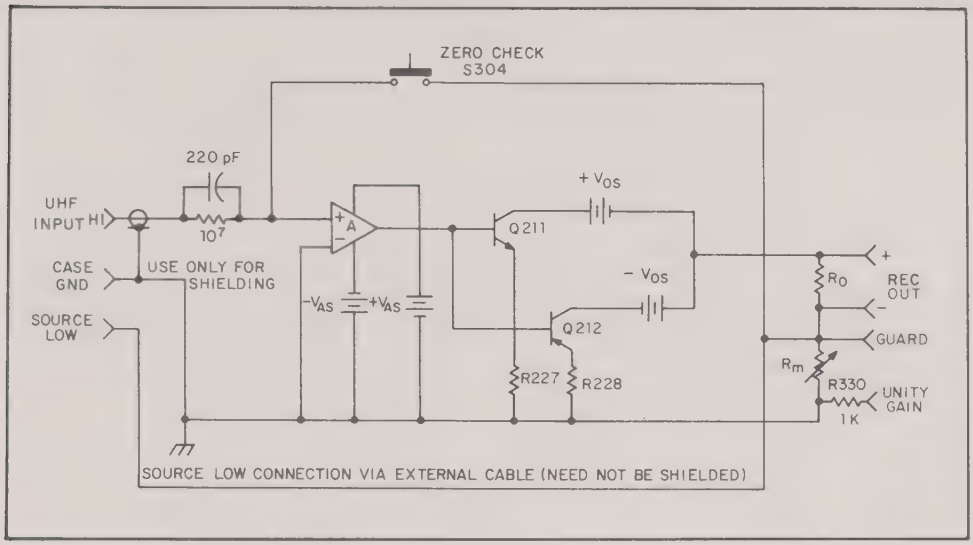


Figure IV-3. FUNCTIONAL DIAGRAM OF THE FEEDBACK METHOD OF VOLTAGE MEASUREMENT

4.4B FEEDBACK METHOD

The feedback method, often referred to as the 'guarded' or 'fast' method, is particularly suitable for making voltage measurements from high source resistances, where the time required to make a measurement by the shunt method might be unduely long. Use of the feedback method eliminates the slowing effect caused by the shunt cable and electrometer input capacitance, as well as the loading errors which might result from stray leakage paths. The input connection in the feedback method is made to the Input UHF connector and to the rear-panel GUARD terminal as shown in Figure IV-3. The following series of steps outlines the feedback method of making voltage measurements.

(1) Set the instrument controls as follows.

Range switch ---------- V
Range Multiplier ---------- 100
Meter Function ---------- ZERO CT.
Zero Check ---------- LOCKED
Mode switch ---------- FEEDBACK

(2) Connect the source voltage to the electrometer as shown in Figure IV-3. Then unlock the Zero Check switch and increase the sensitivity as required to obtain the highest possible on-scale reading.

(3) If desired, set the Meter Function switch to '+' or '-', as appropriate, to obtain an 'end-zero' meter reading.

(4) On the more sensitive ranges, recheck and, if required, readjust the zero by depressing or lock the Zero Check switch and using the front-panel Zero controls.

Note that, in the feedback method of voltage measurement, the Model 134 case ground is not circuit or source low. Case ground is instead common to the rear-panel UNITY GAIN terminal through 1000 ohms.

As in the shunt method, the Model 134 may be zeroed at any time by depressing or locking the Zero Check switch and adjusting the Zero controls. With the Zero Check switch depressed or locked, the source sees 10 MΩ to circuit low. Whenever the Zero Check switch is not depressed or locked, and providing the Range switch is set to 'V', the input resistance is 10^{14} ohms. Lower input resistances can be obtained by selecting any of the current (I) ranges from 10^{-2} A to 10^{-12} A, in which the input resistance is the reciprocal of the selected current range, or 100 ohms to 10^{12} ohms.

4.4C SOURCE RESISTANCE DETERMINATION

When operating the Model 134 as a voltmeter or as an amplifier, in either the SHUNT or FEEDBACK mode, the source resistance of the voltage being measured can be easily determined. A suitable procedure follows.

(1) Note the voltage reading obtained with the Range switch set to 'V'.

(2) Rotate the Range switch through the current ('I') settings, finding one which yields a lower, but still easily read, indication than that recorded in the previous step. Record this lower reading.

(3) Compute the source resistance from the following formula.

$$R_s = \frac{R_e\ (E_s - E_m)}{E_m} \qquad \text{(Equation 1)}$$

where: R_s = source resistance in ohms
R_e = selected electrometer input resistance in ohms (reciprocal of selected current range in step 2)
E_s = measured true voltage with Range switch set to 'V'
E_m = measured voltage with Range switch to one of 'I' settings (step 2 reading)

For example, if the meter reading obtained with the Range switch set to 'V' were reduced 50% when the Range switch was set to 10^{-12} (I), the source resistance would be 10^{12} ohms.

4.5 CURRENT MEASUREMENT

4.5A SHUNT METHOD

The shunt method of current measurement, although generally best suited to making measurements on the higher current ranges, is also useful for low-current measurements in applications where the shunt method 'damping' gives a more stable reading. The input connection in shunt-method current measurements is made at the Input UHF connector as shown in Figure IV-2. The following series of steps outlines this method of making current measurements.

(1) Set the controls as follows.

Range switch ---------- 10^{-2} to 10^{-5}
Range Multiplier ---------- 1 to 100
Meter Function ---------- ZERO CT.
Zero Check ---------- LOCKED
Mode switch ---------- SHUNT

(2) Connect the current source to the electrometer as shown in Figure IV-2. Then unlock the Zero Check switch and increase the sensitivity, using the Range and Range Multiplier switches, as required to obtain a good meter indication.

(3) If desired, set the Meter Function switch to '+' or '-', as appropriate, to obtain an 'end-zero' meter reading.

(4) On the more sensitive ranges, recheck and, if required, readjust the zero by depressing or locking the Zero Check switch and using the front-panel Zero controls. The current source will see 10 MΩ to circuit low with the Zero Check switch depressed.

Note that, in the shunt method of operation, the Model 134 case ground (circuit low) is common with the rear-panel GUARD and REC. OUT (-) terminals.

The input resistance when making shunt mode current measurements is the reciprocal of the selected current range. Thus, the ammeter voltage drop is simply the product of the input current and the ammeter input resistance as determined by the Range switch setting. Input capacitance and capacitive loading provide damping, with the RC product being the capacitance times the input resistance (Range switch setting).

The meter deflection will decrease as the ammeter input resistance approaches the internal resistance of the current source being measured. For example, for a 1% error with a current source having an output resistance of 10^{12} ohms, the smallest Range switch setting would be 10^{-10}, in which the ammeter input resistance would be 10^{10} ohms. For minimum loading error, the ammeter input resistance must be small relative to the current source resistance. Note that loading error is over and above the ammeter error factors in the specifications. In general, it is best to use the Range switch on the largest possible current setting (smallest input resistance) consistent with noise requirements, and with the Range Multiplier on a relatively low setting.

4.5B FEEDBACK METHOD

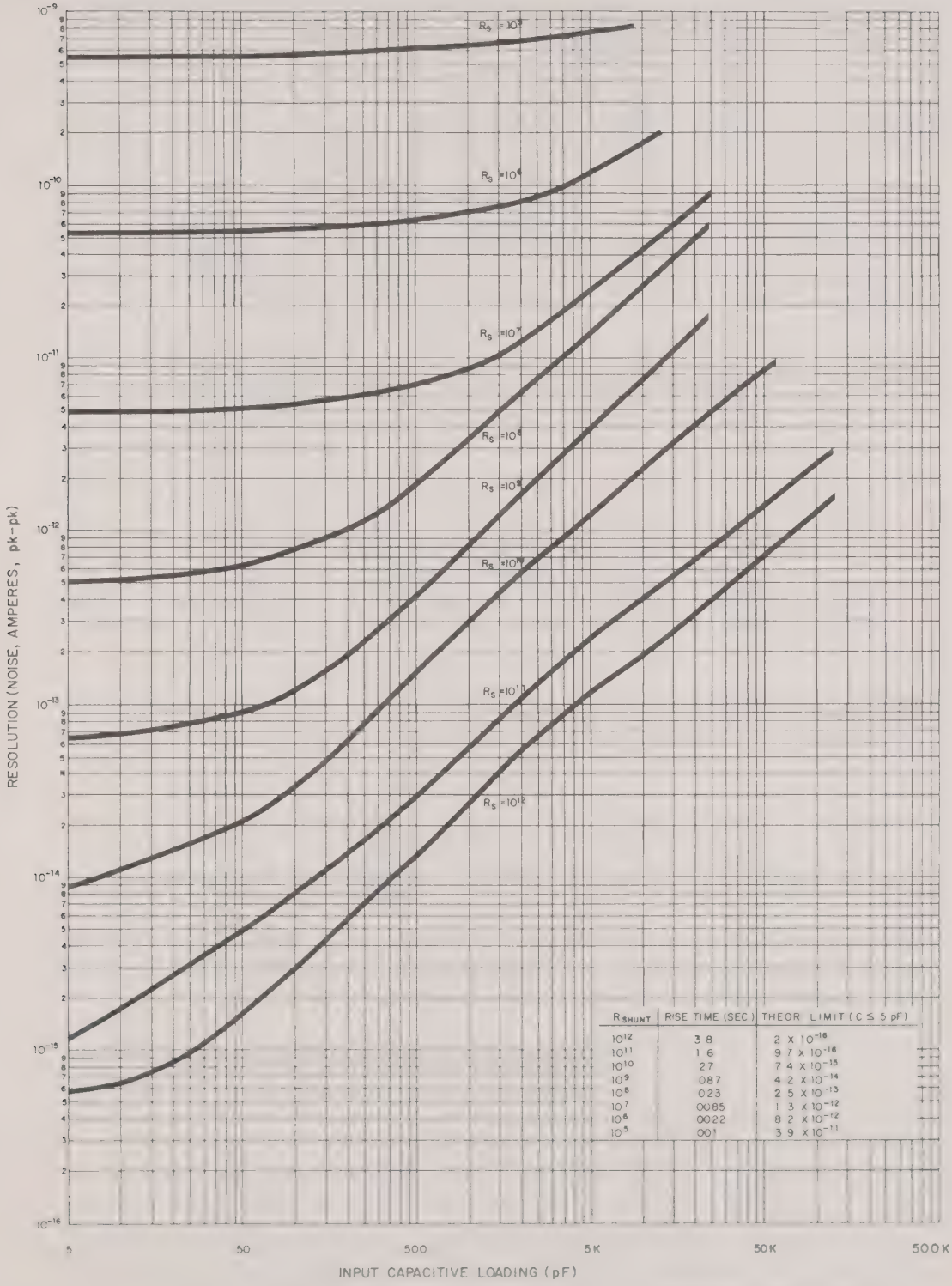
The feedback method of current measurements is particularly useful for measuring very low-level currents, where the slower response time of the shunt method might make the measurement time prohibitively long. Another advantage of feedback operation is that capacitive loading, such as that resulting from the electrometer input capacitance and cable capacitance, does not affect the instrument response speed. Figure IV-4 shows the instrument resolution as a function of capacitance loading for each of the Model 134 current ranges. Although the response time is not affected by capacitive loading in feedback operation, the noise does increase directly with the loading capacitance due to the increasing effect of the voltage noise of the Model 134 input device. However, as shown in Figure IV-4, the higher values of selected feedback resistor (lower current settings of the Range switch) allow the best resolution to be achieved.

In feedback mode current measurements, the ammeter input resistance and the resultant voltage drop are reduced to a small fraction of that in the shunt mode, thus offering 'near ideal' ammeter operation. As such, the measurement is also reasonably insensitive to leakage paths to circuit low. Table IV-3 gives the maximum ammeter input resistance as a function of the Range and Range Multiplier switch settings when the Model 134 is operated in the feedback mode.

RANGE,	RANGE MULTIPLIER						
F.S. AMPERE	.001	.003	.01	.03	.1	.3	1-100
10^{-5}	200	67	20	6.7	2	.67	0.2
10^{-6}	2 k	670	200	67	20	6.7	2
10^{-7}	20 k	6.7 k	2 k	670	200	67	20
10^{-8}	200 k	67 k	20 k	6.7 k	2 k	670	200
10^{-9}	$2X10^6$	670 k	200 k	67 k	20 k	6.7 k	2 k
10^{-10}	$2X10^7$	$6.7X10^6$	$2X10^6$	670 k	200 k	67 k	20 k
10^{-11}	$2X10^8$	$6.7X10^7$	$2X10^7$	$6.7X10^6$	$2X10^6$	670 k	200 k
10^{-12}	$2X10^9$	$6.7X10^8$	$2X10^8$	$6.7X10^7$	$2X10^7$	$6.7X10^6$	$2X10^6$

Table IV-3. MAXIMUM AMMETER INPUT RESISTANCE IN OHMS (FEEDBACK MODE) AS FUNCTION OF RANGE AND RANGE MULTIPLIER SWITCH SETTINGS

In feedback ammeter operation, the connection is made to the Input UHF connector as shown in Figure IV-5. A suitable procedure for making ammeter measurements in the feedback mode follows.



R_{SHUNT}	RISE TIME (SEC)	THEOR LIMIT (C ≤ 5 pF)
10^{12}	3 8	2 X 10^{-16}
10^{11}	1 6	9 7 X 10^{-16}
10^{10}	27	7 4 X 10^{-15}
10^{9}	087	4 2 X 10^{-14}
10^{8}	023	2 5 X 10^{-13}
10^{7}	0085	1 3 X 10^{-12}
10^{6}	0022	8 2 X 10^{-12}
10^{5}	001	3 9 X 10^{-11}

Figure IV-4. CURRENT RESOLUTION AS A FUNCTION OF RANGE AND INPUT CAPACITIVE LOADING

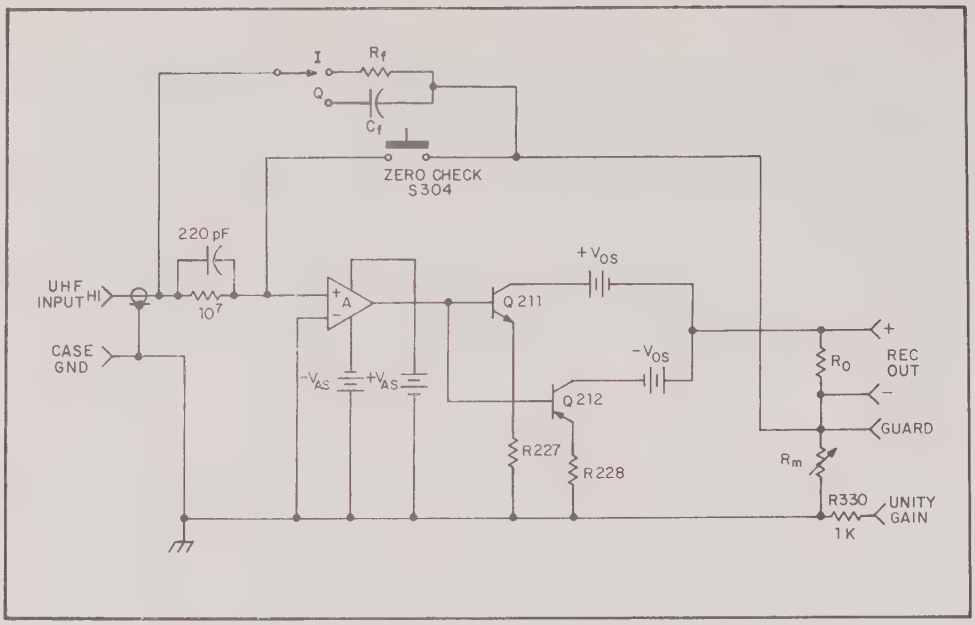


Figure IV-5. FUNCTIONAL DIAGRAM FOR FEEDBACK CURRENT AND CHARGE MEASUREMENTS

(1) Set the controls as follows.

Range switch	10^{-5}
Range Multiplier	100
Meter Function	ZERO CT.
Zero Check	LOCKED
Mode switch	FEEDBACK

(2) Connect the current source to the electrometer as shown in Figure IV-5. Then unlock the Zero Check switch and increase the sensitivity with the Range and Range Multiplier switches as required to obtain a good meter indication.

(3) If desired, set the Meter Function switch to '+' or '-', as appropriate, to obtain an 'end-zero' meter reading.

(4) On the more sensitive ranges, recheck and, if required, readjust the zero by depressing or locking the Zero Check switch and using the front-panel Zero controls. With the switch depressed or locked, the current source sees 10 MΩ to circuit low.

Note that the ammeter input resistance in the feedback method of measurement is reduced by the amplifier loop gain (Table IV-3). As a result, the input voltage drop is reduced to below 100 μV for most ranges. Also, the response speed is increased and not affected by external capacitive loading. The response speed for each range is that given in the specifications.

The output resistance of the current source being measured (feedback mode operation) should be no less than .01 of the selected Range Resistor (reciprocal of selected range). Lower values of source resistance will not introduce error, but will increase the zero drift and noise proportionally.

Current ranges above 10^{-5} should not be used in feedback operation. Excessive errors will occur on the 10^{-4} to 10^{-2} ranges because the measured current becomes a significant addition to the electrometer full-scale output circuit current indicated by the meter (1 mA full scale).

NOTE: IN EITHER MODE OF CURRENT MEASUREMENT, THE MODEL 134 CAN BE USED AS A CURRENT NULL-DETECTOR (GALVANOMETRIC METHOD) WITH AN EXTERNAL CURRENT SOURCE SUMMING INTO THE ELECTROMETER INPUT. ALSO, THE ELECTROMETER ZERO CONTROLS MAY BE USED TO OFFSET THE METER WITHOUT SACRIFICING THE INPUT DYNAMIC RANGE.

In feedback operation, the Model 134 case ground (circuit low) is common, through 1000 ohms, with the rear-panel UNITY GAIN terminal. Case ground is not common with REC. OUT low (-) or GUARD in feedback operation and no such connection should be made.

4.6 RESISTANCE MEASUREMENT

4.6A SHUNT METHOD

The shunt method of resistance measurement (Figure IV-6), while it can be used for measuring the resistance of high-valued resistors, is best suited to measuring resistance up to 10^{11} ohms. A suitable procedure for making shunt

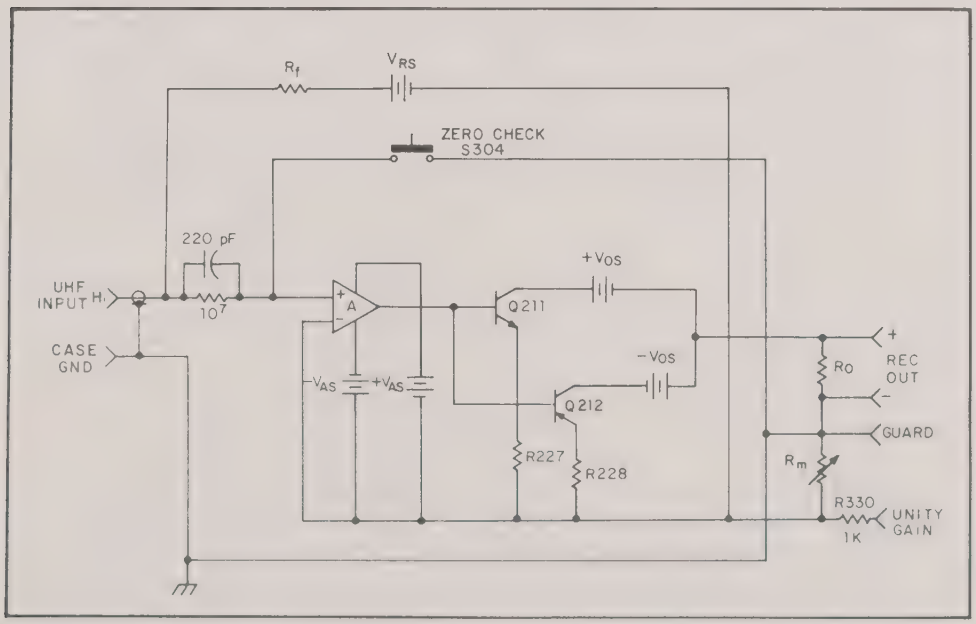


Figure IV-6. FUNCTIONAL DIAGRAM OF SHUNT RESISTANCE MEASUREMENT

method resistance measurements follows.

(1) Set the controls as follows.

Range switch ---------- 10^5
Range Multiplier ---------- 1 to 100
Meter Function ---------- ZERO CT.
Zero Check ---------- LOCKED
Mode switch ---------- SHUNT

(2) Connect the resistance sourrce directly to the Input UHF connector as shown in Figure IV-6. Then unlock the Zero Check switch and increase the sensitivity, using the Range switch and Range Multiplier, as required to obtain a good meter reading.

(3) If desired, set the Meter Function switch to '+' or '-', as appropriate, to obtain an 'end-zero' meter reading.

(4) On the more sensitive ranges, recheck and, if required, readjust the zero by depressing or locking the Zero Check switch and using the front-panel Zero controls. With the Zero Check switch depressed or locked, the resistance source will see 10 MΩ to ground. Zero checking can be done at any time.

Note that, in shunt resistance operation, the Model 134 case ground (circuit low) is common with the rear-panel GUARD and REC. OUT (-) terminals.

4.6B FEEDBACK METHOD

The feedback method of measuring resistance (Figure IV-7) is particularly useful when measuring very high valued resistors, where it is much faster than the shunt method. This stems from the response time in feedback operation being independent of capacitive loading, either from the electrometer input capacitance or from cable capacitance. Further, in feedback operation the effects of leakage paths from source high to Model 134 case ground are minimized. A suitable procedure for making feedback resistance measurements follows.

(1) Set the controls as follows.

Range switch ---------- 10^5
Range Multiplier ---------- 100
Meter Function ---------- ZERO CT.
Zero Check ---------- LOCKED
Mode switch ---------- FEEDBACK

(2) As shown in Figure IV-7, connect the 'high' side of the resistance source to the center conductor of the Input UHF connector and connect source 'low' to the rear panel GUARD terminal.

(3) Unlock the Zero Check switch and increase the sensitivity with the Range and Range Multiplier switches as required to obtain a good meter indication.

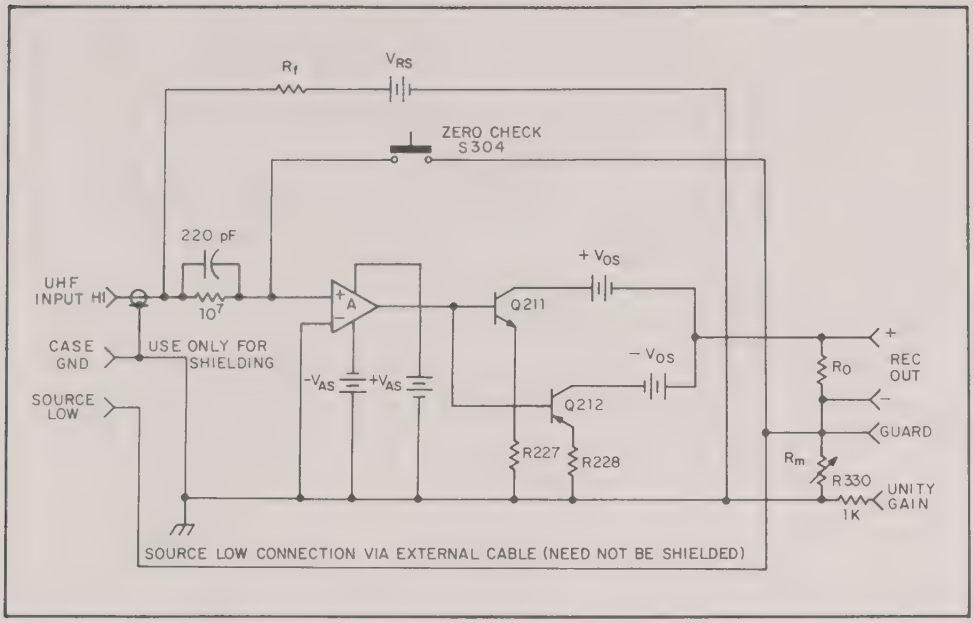


Figure IV-7. FUNCTIONAL DIAGRAM OF FEEDBACK METHOD OR MEASURING RESISTANCE

(4) If desired, set the Meter Function switch to '+' or '-', as appropriate, to obtain an 'end-zero' meter reading.

(5) On the more sensitive ranges, recheck and, if required, readjust the zero by depressing or locking the Zero Check switch and using the front-panel Zero controls. With the Zero Check switch depressed or locked, the resistance source sees 10 MΩ to circuit low.

NOTE: WHEN CHANGING RANGES WITH THE RANGE SWITCH, IT IS ADVISABLE, ESPECIALLY WITH HIGHER VALUED RESISTORS, TO ZERO CHECK WHEN SO DOING. THIS ASSURES FREEDOM FROM TRANSIENTS, FAST RESPONSE AND RECOVERY, AND DISCHARGE OF STRAY CAPACITANCES.

Note that the Model 134 case ground is not circuit or source low in feedback operation, and is common to the rear-panel UNITY GAIN terminal through 1000 ohms.

4.6C CONSTANT CURRENT SOURCE OPERATION

The Model 134 measures resistance by applying a true constant current to the sample, with the resultant voltage across the sample being read on the panel meter. In applications which require a constant current source, the Model 134 can be used. Possible applications might include measurement of the I-V characteristics of diodes and capacitor charging and decay studies.

Because the Range Multiplier switch not only acts as a multiplier, but also

sets the full-scale voltage at the input, the electrometer can be used as a constant current source with a variable output compliance voltage limit. The current output is the reciprocal of the Range switch setting (R), and the compliance limit is the Range Multiplier setting. Thus, compliance limits as high as 100 V can be selected. Positive output current only is provided.

NOTE: WITH THE INPUT OPEN, AS MUCH AS 100 V WILL BE AVAILABLE AT THE INPUT (RANGE MULTIPLIER SET TO 100). CARE MUST BE TAKEN TO AVOID ELECTRICAL SHOCK.

Either feedback or shunt operation is possible when the instrument is used as a constant current source. See the preceding two subsections on resistance measurements for grounding and input connection information.

An ideal constant current source exhibits infinite output resistance. The output resistance of the Model 134 as a function of the Range and Range Multiplier switch settings, is shown in Table IV-4. As can be seen, the output resistance of the Model 134 is extremely high for all settings in constant current operation.

RANGE SWITCH	OUTPUT CURRENT	RANGE MULTIPLIER						
		.001	.003	.01	.03	.1	.3	1-100
10^{5}	10^{-5}	$5X10^{7}$	$1.5X10^{8}$	$5X10^{8}$	$1.5X10^{9}$	$5X10^{9}$	$1.5X10^{10}$	$5X10^{10}$
10^{6}	10^{-6}	$5X10^{8}$	$1.5X10^{9}$	$5X10^{9}$	$1.5X10^{10}$	$5X10^{10}$	$1.5X10^{11}$	$5X10^{11}$
10^{7}	10^{-7}	$5X10^{9}$	$1.5X10^{10}$	$5X10^{10}$	$1.5X10^{11}$	$5X10^{11}$	$1.5X10^{12}$	$5X10^{12}$
10^{8}	10^{-8}	$5X10^{10}$	$1.5X10^{11}$	$5X10^{11}$	$1.5X10^{12}$	$5X10^{12}$	$1.5X10^{13}$	$5X10^{13}$
10^{9}	10^{-9}	$5X10^{11}$	$1.5X10^{12}$	$5X10^{12}$	$1.5X10^{13}$	$5X10^{13}$	$1.5X10^{14}$	$5X10^{14}$
10^{10}	10^{-10}	$5X10^{12}$	$1.5X10^{13}$	$5X10^{13}$	$1.5X10^{14}$	$5X10^{14}$	$>10^{15}$	$>10^{15}$
10^{11}	10^{-11}	$5X10^{13}$	$1.5X10^{14}$	$5X10^{14}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$
10^{12}	10^{-12}	$5X10^{14}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$

Table IV-4. DYNAMIC OUTPUT RESISTANCE IN OHMS (CONSTANT CURRENT OPERATION) AS A FUNCTION OF THE RANGE AND RANGE MULTIPLIER SWITCH SETTINGS

4.7 CHARGE MEASUREMENT

4.7A SHUNT METHOD

The shunt method of charge measurement (Figure IV-2) may be used when the output resistance of the charge source is 'near ideal' or extremely high. Further, voltage measurements accompanied by damping or long integration times may be made, with the time constant being the product of the source's output resistance and the charge range selected (capacitance in farads). A

suitable procedure follows.

(1) Set the controls as follows.

Range switch ---------- 10^{-7}
Range Multiplier ---------- 100
Meter Function ---------- ZERO CT.
Zero Check ---------- LOCKED
Mode switch ---------- SHUNT

(2) As shown in Figure IV-2, connect the charge source directly to the Input UHF connector. Then unlock the Zero Check switch and increase the sensitivity with the Range and Range Multiplier switches as required to obtain a good meter indication.

(3) If desired, set the Meter Function switch to '+' or '-', as appropriate, to obtain an 'end-zero' meter reading.

Note that, in shunt operation, the Model 134 case ground (circuit low) is common to the rear-panel GUARD and REC. OUT (-) terminals.

Zeroing of the Model 134 may be performed at any time by depressing or locking the Zero Check switch, at which time the charge source will see 10 MΩ to circuit low. When changing ranges, zero check for 20-30 seconds on the 10^{-7} range, and at least five seconds on the other ranges. This allows proper reset action by sufficiently discharging the capacitor. After releasing the Zero Check switch, increase the sensitivity with the Range Multiplier switch. Zero checking places a finite fixed charge on the capacitor, due to transient effects. The 'feel' of zero-checking and releasing will be realized, and the offset can be zeroed out with the front-panel Zero controls without sacrificing input dynamic range.

4.7B FEEDBACK METHOD

The feedback method of charge measurement (Figure IV-5) is recommended where a linear display with time is desired, and where the output resistance of the charge source is considerably less than 'ideal'. Also, capacitive loading, particularly on most sensitive charge ranges, does not affect measurement accuracy. A suitable procedure follows.

(1) Set the controls as follows.

Range switch ---------- 10^{-7}
Range Multiplier ---------- 100
Meter Function ---------- ZERO CT.
Zero Check ---------- LOCKED
Mode switch ---------- FEEDBACK

(2) Connect the charge source directly to the electrometer Input UHF connector (Figure IV-5). Then increase the sensitivity with the Range and Range Multiplier switches as required to obtain a good meter indication.

(3) If desired, set the Meter Function switch to '+' or '-', as appropriate, to obtain an 'end-zero' meter reading.

Note from Figure IV-5 that the Model 134 case ground (circuit low) is common, through 1000 ohms, with the rear-panel UNITY GAIN terminal.

Zeroing of the Model 134 can be performed at any time by depressing or locking the Zero Check switch. When this switch is depressed or locked, the charge source sees 10 MΩ to circuit low. When changing range, zero check for 20-30 seconds on the 10^{-7} range, and at least five seconds on the other ranges. This allows proper reset action by giving the capacitor sufficient time to discharge. However, zero check release does place a finite fixed charge on the capacitor due to transient effects. The 'feel' of zero-checking and releasing is soon realized, and the offset can be zeroed out with the front-panel Zero controls without sacrificing input dynamic range.

NOTE: Direct integration of current source outputs, such as photomulitplier outputs, ionization detectors, etc., can be accomplished. The Range Multiplier acts as a multiplier, extending operation to 10^{-13} coulomb full scale. Polystyrene, low-leakage capacitors are used, and the Range Multiplier setting directly indicates (for full scale) the voltage build up across the capacitor. Thus, knowing the integration time, and reading the charge (Q) and voltage (V) directly on the meter, 'I' can be computed as

$$I = Q/t = CV/t \qquad \text{(Equation 2)}$$

where C = capacitance in farads

The capacitance values, for the four ranges, are as follows.

Range Setting (Q)	Capacitor
10^{-7} C	0.1 µF
10^{-8} C	0.01 µF
10^{-9} C	1000 pF
10^{-10} C	100 pF

Resolution of better than 5×10^{-16} A is possible when operated as a rate-of-charge picoammeter or coulombmeter. Input capacitive loading does not affect the accuracy or linearity, because operation is in the Feedback mode. Note that, if the Model 134 is left unconnected, its own input offset current will charge the internal range capacitor at a rate no greater than $\pm 3 \times 10^{-15}$ A/s.

SECTION V
CIRCUIT DESCRIPTION

5.1 INTRODUCTION

This section of the manual discusses the functioning of the Model 134 circuitry. An assumption underlying this material is that the reader has a basic understanding of operational amplifiers, transistors, and related electronic components. The circuit description serves a two-fold purpose. First, the user may be interested in the internal workings of the instrument from an academic standpoint. Secondly, a basic knowledge of the Model 134 circuitry can be of value in servicing the instrument.

The Model 134 basically consists of a high-input impedance, high-gain, operational amplifier with its accompanying plus and minus low-voltage (±9 V) power supplies, and a unity-gain output amplifier (complementary symmetry stage) with its accompanying plus and minus high-voltage (±120 V) power supplies.

Refer to the schematics in Section IX when studying the circuit descriptions.

5.2 INPUT BOARD (schematic on page IX-4)

As can be seen from the Amplifier Board schematic on page IX-4, the input stage of the Model 134 is an MOS (metal-oxide-semiconductor) device, Q101. The gain of the input amplifier, which consists of Q101, Q102, CR101, CR102, and, on the amplifier board, R102, R103, R104, and C101, is typically sixteen.

Q102, the dual low-leakage transistor connected to the input (high impedance) gate of Q101, provides gate protection for Q101. This protection is accomplished through Zener breakdown of either base-emitter junction of Q102 as determined by the polarity of the input overload level. Zener action occurs with an input overload current of as little as 5 pA, thus clamping the gate of Q101 at a potential in the range of six to eight volts.

Diodes CR101 and CR102 provide first-stage clamping action under overload, such that neither drain of Q101 will go into deep saturation. The maximum drain-to-drain voltage under overload is limited to 0.7 V.

The other gate electrode of Q101 is used for zeroing the Model 134. Because it is always terminated in a low impedance, this gate requires no overload protection device.

5.3 AMPLIFIER BOARD (schematic on page IX-4)

The remaining voltage amplification is accomplished on the amplifier board. Besides the amplifier stages, this board also has on it Q103, the constant current source that supplies a constant current of 200 μA to the MOS input amplifier stage.

Transistors Q104 and Q105, along with their associated components, form an emitter follower stage which buffers the output of the input amplifier to present a low impedance drive to the next voltage amplifier stage. Further, R102 and C101 provide low frequency compensation to assure a controlled gain-frequency roll-off characteristic.

The junction of R105 and R106-R107 provides a reference point for the base of constant current device Q103. Any input condition which tends to change the MOS drain current will reflect a change at this junction. Q103 will then invert this change, thus applying a corrective action and maintaining the current to the first stage constant at 200 μA.

CR103 and CR104 are back-to-back connected base-emitter junctions of transistors which clamp the base of Q103 under overload conditions. These devices clamp the base of Q103 to the amplifier power supply common, thus maintaining Q103 in operation under overload. The clamping voltage is in the range of 7.5 to 8.5 V.

Transistors Q106 and Q107, along with collector load resistors R108 and R109, comprise the second voltage amplifier stage. This stage has a typical voltage gain of 120. R110 and C102 provide mid-frequency compensation to help assure a controlled gain-frequency roll-off characteristic. R111 provides emitter biasing for Q106 and Q107, nominally 100 μA.

Q108 and Q109 are modified emitter follower transistors that provide a low-impedance drive to the output voltage gain stage. Q109, itself an emitter follower, serves as an active load for emitter follower Q108.

The final voltage gain stage is made up of transistors Q110, Q111, and Q112, along with associated resistors R112 through R116, and capacitor C103. Emitter follower Q110 provides a low-impedance drive to voltage gain transistor Q111. Q111 has Q112 as an active collector load, and so has a very high unstabilized gain. Resistors R113 and R112 stabilize the voltage gain of Q111 to a nominal value of 330, and also serve, along with R114, R115, and R116, as biasing for Q111. The final gain-stage current is always about 120 μA, even under overload. Thus the stage cannot saturate or lock up under severe overload. The extremely high unstabilized voltage gain assures that the nominal stage gain of 330 will be stable. This high gain is achieved by driving the base and emitter of Q111 with opposing polarity voltage changes, and by providing a very high-impedance load, Q112. Capacitor C103 provides high-frequency compensation and therefore a controlled gain-frequency roll-off characteristic.

Emitter follower Q113, the last stage of the amplifier, serves to present a low impedance source to the output amplifier stage. Further, Q113 prevents loading of the high-impedance voltage gain stage, Q111. The load for emitter follower Q113 is located on the mother board. R117, in the collector circuit of Q113, is for current limiting purposes.

5.4 OUTPUT AMPLIFIER (schematic on page IX-3)

Transistors Q211 and Q212, located on the mother board, form a unity-gain, complementary symmetry output amplifier stage powered from a separate ±120 V

power supply. Bias for the stage is obtained from the series combination R226, R234, and CR209 to assure that Q211 and Q212 conduct at all times. R226, R234, and CR209 also serve as the load for emitter follower Q113, discussed earlier. CR209 provides temperature compensation for Q211 and Q212, while R226 serves to adjust the quiescent current in the complementary output stage.

CR210 through CR213, together with R227 and R228, serve to limit the output amplifier current. Thus, the maximum collector current of Q211 is limited to a value determined by the voltage drop across CR210 and CR211, nominally 1.4 V. The collector current cannot increase beyond the point where the sum of the Q211 base-emitter drop and the voltage across R227 equal 1.4 V. CR212, CR213, and R228 similarly limit the maximum collector current of Q212.

5.5 LOW VOLTAGE POWER SUPPLY (schematic on page IX-3)

As can be seen from the schematic on page IX-3, the ±9 V supplies are highly regulated. CR201 is a full-wave bridge, converting the transformer ac output to ±36 V unregulated dc. Because the two regulators are virtually identical in function, only the positive regulator is discussed.

The unregulated +36 V is filtered by capacitor C201. R201 and CR203 form a simple pre-regulator circuit, establishing a moderately low-ripple +24 V. At this point, the line regulation is such that for a 10% line voltage change, the 24 V level will not shift more than 80 mV (0.33%).

Current source Q203, independent of line-voltage fluctuations, provides a constant current to CR205, the Zener diode that determines the output voltage of the power supply. C208 provides output filtering, reducing the Zener diode noise.

The operating point of Q203 is established by Q201, Q202, R202, R203, and R204. Further, Q201 is a transistor connected as a Zener reference diode, the base emitter junction being the reference diode and the collector-base junction being forward biased for temperature compensation. Transistor Q202 serves as an amplifying stage, having a gain of approximately 50. The current through R202 is determined and controlled by comparison with the voltage drop across Q201 and the Q202 base-emitter voltage drop. Any input change which tends to change the voltage across R202 is corrected by Q202. Thus, for example, should the current through R202 tend to increase, the base voltage of Q202 will increase, turning Q202 on harder. This change is amplified, with the collector of Q202 decreasing and thus turning off Q203. The result is a reduction in the Q203 output current and a return of the output current to its original value. By maintaining the output current of the supply constant, the Zener voltage of CR205, relative to input variations, is maintained constant as well.

Q202, the amplifying stage, may be considered as an inverting, single-stage, operational amplifier with an open-loop voltage gain of 50. Q203 and R203 form the feedback loop, closing the loop to essentially unity. Any change in the R202 voltage, and thus the output current, causes a change in the Q203 base-emitter voltage. As a result of the operational amplifier, any

change is reduced by a factor of 50.

The amplifying action of Q202 serves also to reduce the power supply ripple in the same manner as absolute line changes are reduced. Thus, the amount of ripple component at the output of the supply is extremely low. Q202 also limits the output current to a set value, providing short-circuit protection.

The regulation due to the amplifying action of Q202 is simply the ratio of the output impedance of Q203 to the dynamic impedance of CR205, or a minimum of 1000:1. Thus a 10% line change, which would cause an 80 mV change in the 24 V pre-regulator voltage, would cause a change of less than 80 μV in the +9 V output.

With the exception of polarity and transistor changes, the negative section of the supply is identical. The ±9 V outputs of these regulators power the Model 134 amplifier.

5.6 ZERO ADJUST CIRCUITRY (schematics on pages IX-2 and IX-3)

A variable zero-offset potential is provided to the MOS input stage to balance offsets in the input device and to provide a variable input voltage offset useful for bucking out residual input dc potentials. Three controls are provided, FINE, COARSE, and ZERO RANGE (R313, S303, and S307 respectively), giving a total zero offset capability of ±110 mV.

Referring to the schematic on page IX-3, note that R222-R223 and R225-R224 form two voltage dividers to obtain ±110 mV from the ±9 V supply levels. This ±110 mV is then applied to the Kelvin-Varley zero circuitry, as shown on the schematic on page IX-2.

The Kelvin-Varley zero circuitry comprises R313 (Fine Zero), S307 (Zero Range), associated precision resistors R314-R324, S303 (Coarse Zero), and associated precision resistors R130-R139. The output of the Kelvin-Varley divider is then made available to the MOS gate for variable zero offset purposes.

All components of the Model 134 Zero Adjust circuitry are selected for very high time and temperature stability, to assure that the Zero Adjust circuitry does not contribute significantly to the input drift of the instrument.

5.7 HIGH VOLTAGE POWER SUPPLY (schematic on page IX-3)

Referring to the schematic, note that the ±120 V supply is not as highly regulated as the ±9 V supply described earlier. This is because the output amplifier does not require as highly regulated supply voltages as the low signal amplifiers which preceded it. Considering the function of the individual components, CR202 is a full-wave bridge, converting the transformer high-voltage ac to ±205 V. This voltage is applied to the two regulators. Because the operating principles of both regulators are the same, only the positive regulator is discussed.

Current source Q207 supplies a constant current to Zener diode CR207, which

determines the +120 V output. Q207 is biased by Q208, R210, R211, R212, and R213. Q208, analogous in function to Q202 in the low voltage supply, serves as an amplifier to maintain the output current of Q207. The current regulation of Q207 is only moderate, however, due to not utilizing a reference source for Q208. The regulation of the high-voltage supply is simply the ratio of the output impedance of Q207 to the dynamic impedance of CR207, or a minimum of 200:1. Short-circuit protection, which is in the low-voltage supply, is provided. Further, capacitor C210 serves to reduce the Zener diode noise to an acceptable level.

Note that, by providing a current for CR207, the raw dc (±205 V) is able to be lower than that which would be required if a simple series resistor were used for the CR207 biasing.

With the exception of polarity and transistor changes, the negative regulator is identical.

5.8 METER CALIBRATE, ZERO CENTER (schematic on page IX-3)

The Model 134 uses a 1 mA taut-band meter movement having a tracking spec. of ±0.5% worst case and an accuracy of 5%. The Meter Cal. adjustment, R233 in series with R232, shunts the meter movement and allows precise full-scale accuracy adjustment. R233 is a single-turn, high-quality, cermet-element potentiometer, allowing exact adjustment free from effects of environment and vibration.

The Model 134 can operate in a center-zero mode useful for null detection and whenever the user wishes zero center operation. Operation in this mode is made possible via the ZERO CT. position of the Meter Function switch by Q213, R229, R230, and R231. Q213 operates as a Zener reference diode, the base-emitter junction being the Zener reference and the collector-base junction, forward biased, serving as temperature compensation. R229 biases the Zener reference diode by supplying current from the +120 V supply level. A current of 500 µA (half the full-scale meter current) is supplied from the constant voltage determined by Q213; the 500 µA is exactly adjustable by the ZERO CT. CAL potentiometer, R230, which is in series with R231. R230 is a single-turn, high-quality, cermet-element potentiometer that allows exact adjustment free from the effects of environment or vibration.

5.9 R-CALIBRATE ADJUST (schematic on page IX-3)

When used as an ohmmeter, the Model 134 provides a constant current output as determined by the Range switch setting (R_f) and a precision 1 V reference (V_{RS}), as previously discussed in Section IV of this manual. The one volt reference is obtained from a voltage divider consisting of R219, R220, and R221 connected to the +9 V supply.

R219, the R-CAL potentiometer, enables the 1 V reference to be exactly set. R219 is a single-turn, high-quality, cermet-element potentiometer, allowing exact adjustment free from the effects of environment and vibration.

5.10 RANGE MULTIPLIER (schematics on pages IX-2 and IX-4)

The Range Multiplier switch serves as a multiplier for full-scale voltmeter,

ammeter, ohmmeter, and coulombmeter operation, and as a means of voltage full-scale range selection. This switch, S305, is specially designed to reduce the effects of contact resistance to an absolute minimum through the use of rotor and stator elements of silver alloy plated with solid silver. The extremely low contact resistance achieved is designed to be maintained for over 100,000 operations. Further, four-terminal, current-voltage connections to the switch are utilized to achieve error-free electrical contact.

The Range Multiplier resistors, R118-R128, are precision (±0.1%) devices of low thermal construction. R118, R119, and R120 are wirewound, necessary because of their low resistance values. R121-R128 are high-quality metal film resistors.

5.11 RANGE SWITCH (schematic on page IX-2)

The Range switch, S306, serves to enable ranging and function selection. This switch is also of special design, with the forward section near the front panel being the high-impedance section. The rotor and stator components, like those of the Range Multiplier switch, are designed for in excess of 100,000 trouble-free operations.

Capacitors C301-C304, mounted on the Range switch, are low-leakage polystyrene capacitors. These are used for charge measurements.

Resistors R301-R311, mounted on the Range switch, are the resistors used for ammeter and ohmmeter operation. R301-R306 are selected and aged, high-megohm devices. R307-R310 are metal-film resistors, while R311, because of its low resistance and required power rating, is a wirewound resistor.

Capacitors C305-C312, mounted on the Range switch, shunt R301-R308 to provide predetermined damping for the 10^{-5} through 10^{-11} A current ranges. The damping time constants provided range from .001 s to 2 s. Like C301-C304, these are low-leakage polystyrene capacitors.

SECTION VI
ALIGNMENT PROCEDURE

6.1 INTRODUCTION

The Model 134 Electrometer is a reliable, conservatively designed instrument, and as such, should provide long dependable service. However, to be assured of continued high confidence in the data obtained through use of the Model 134, it is advisable to run through the following alignment procedure at one year intervals. Also, after any repair work, the entire alignment procedure should be run through.

NOTE: Check high-megohm range resistor accuracy per the alignment procedure, or with an accurate high-megohmmeter* (accuracy of at least 1% overall), at six-month intervals.

Note that these checks and adjustments are not intended to be used as a troubleshooting procedure. The basic assumption underlying this section is that the instrument is functioning normally. Appropriate information on isolating malfunctions is located in the following section. If it is malfunctioning, or is suspected of same, follow the procedures outlined in Section VII to isolate and remedy the problem.

The operator is advised to follow the alignment procedure in the order written, and in its entirety. Note that the alignment procedure calls for specific equipment to be utilized. However, the operator may substitute equivalent instrumentation for the recommended equipment.

Refer to Figures VI-1, 2, and 3 for the location of the components and test points.

6.2 EQUIPMENT NEEDED

(1) HP Model 6111A Voltage Source (accuracy known to better than ±.1% of setting).

(2) Tektronix RM561A Scope, Type 3A6 Vertical Plug-in.

(3) Fairchild M7000A Digital Voltmeter.

(4) General Radio GR1310-A Oscillator.

(5) Ballantine M320A True RMS Meter.

(6) Moseley M680 Chart Recorder.

(7) PAR Model 280 High Voltage Supply.

*Recommended to the user is the Guildline Model 9520 Teraohmmeter, Guildline Instruments, Ltd.

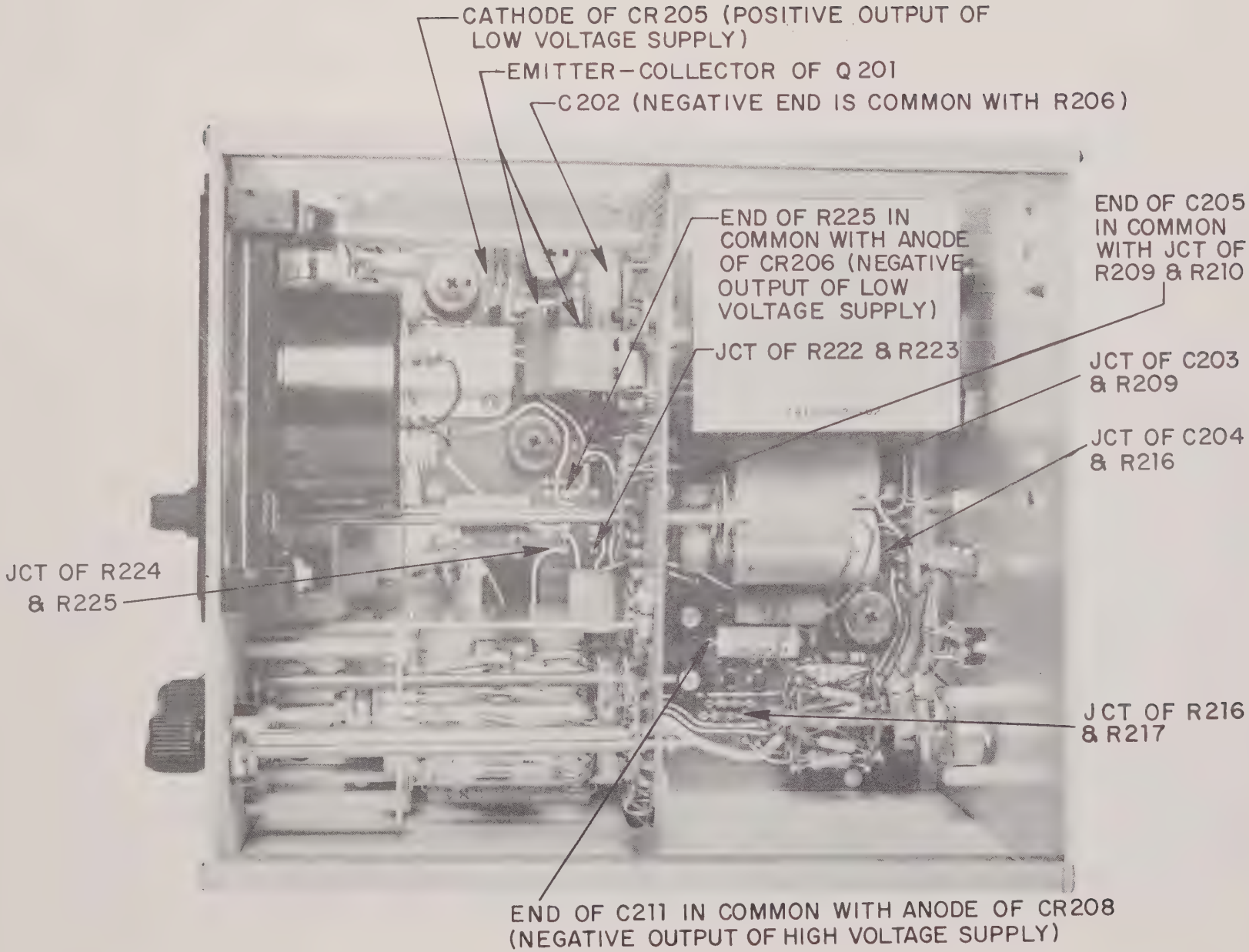

CATHODE OF CR205 (POSITIVE OUTPUT OF LOW VOLTAGE SUPPLY)
EMITTER-COLLECTOR OF Q201
C202 (NEGATIVE END IS COMMON WITH R206)
END OF R225 IN COMMON WITH ANODE OF CR206 (NEGATIVE OUTPUT OF LOW VOLTAGE SUPPLY)
JCT OF R222 & R223
END OF C205 IN COMMON WITH JCT OF R209 & R210
JCT OF C203 & R209
JCT OF C204 & R216
JCT OF R224 & R225
JCT OF R216 & R217
END OF C211 IN COMMON WITH ANODE OF CR208 (NEGATIVE OUTPUT OF HIGH VOLTAGE SUPPLY)

Figure VI-1. TOP VIEW OF MODEL 134

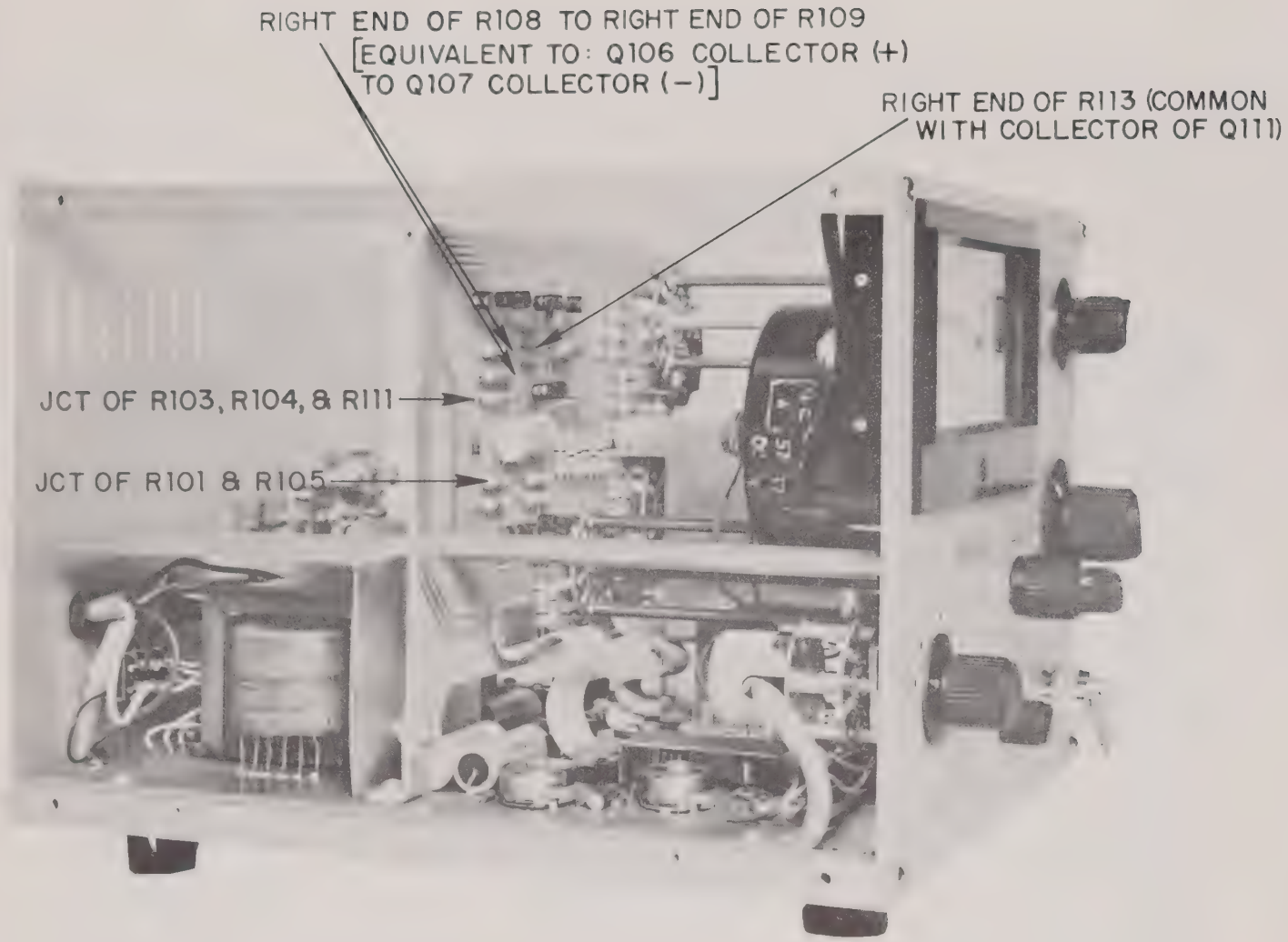

RIGHT END OF R108 TO RIGHT END OF R109
[EQUIVALENT TO: Q106 COLLECTOR (+)
TO Q107 COLLECTOR (−)]
RIGHT END OF R113 (COMMON
WITH COLLECTOR OF Q111)
JCT OF R103, R104, & R111
JCT OF R101 & R105

Figure VI-2. LEFT SIDE VIEW OF MODEL 134

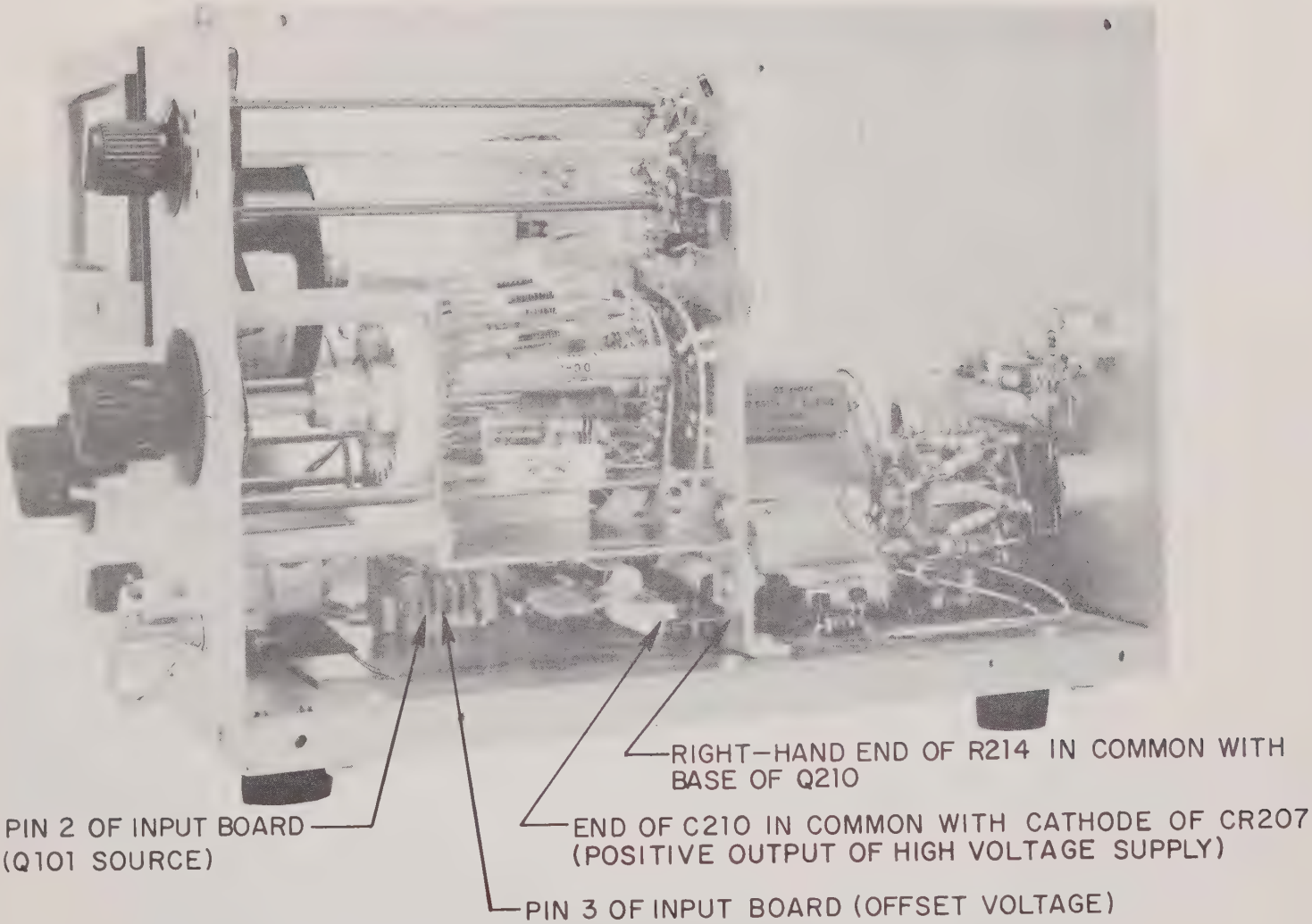

RIGHT-HAND END OF R214 IN COMMON WITH BASE OF Q210
PIN 2 OF INPUT BOARD (Q101 SOURCE)
END OF C210 IN COMMON WITH CATHODE OF CR207 (POSITIVE OUTPUT OF HIGH VOLTAGE SUPPLY)
PIN 3 OF INPUT BOARD (OFFSET VOLTAGE)

Figure VI-3. RIGHT SIDE VIEW OF MODEL 134

(8) Voltage Divider Box, 1:1, 10:1, 100:1, and 1000:1.

(9) PAR Hi-Megohm Standards*.

(10) Adapter, UHF plug/BNC jack, PAR part no. 2102-0080-06.

(11) Assorted required BNC cables, adapters, test leads.

*NOTE: PAR high-megohm standards, 10^7 ohms through 10^{12} ohms, are maintained at the factory. Standard resistors, suitable for ammeter and ohmmeter accuracy verification, are available from PAR as follows:

PAR MODEL NO.	DESCRIPTION
134/52	10^7 ohm
134/53	10^8 ohm
134/54	10^9 ohm
134/55	10^{10} ohm
134/56	10^{11} ohm
134/57	10^{12} ohm

6.3 PRELIMINARY PROCEDURE

(1) Remove the top and bottom covers from the Model 134.

(2) Adjust the panel meter mechanical zero exactly. Tilt the instrument 45° both right and left of horizontal. ZERO SHIFT MUST NOT EXCEED ±0.5% OR ONE-HALF OF A MINOR DIVISION.

(3) Physically jar the instrument and observe that the panel meter mechanical zero does not shift.

(4) Set the Model 134 operating controls as follows.

Meter Function	PWR. OFF
Mode	FEEDBACK
Zero Check	LOCKED
Range Multiplier	10 V
Range Switch	V
1 V/1 mA Switch	1 V

(5) Apply power to the Model 134 and set the Meter Function to ZERO CT. The meter should advance up-scale. Increase the sensitivity with the Range Multiplier and check for basic operation of the Fine Zero, Coarse Zero, and Zero Range controls.

(6) With the Meter Function switch in the + position, the Fine and Coarse Zero controls should deflect the meter positive (up-scale) for clockwise motion. Check that the zero controls swing the meter pointer through zero. Establish a good zero on the most sensitive range.

(7) Allow the Model 134 to warm up for five minutes.

6.4 POWER SUPPLIES

(1) Using the M7000A Digital Voltmeter, check for proper operating voltages as outlined in Tables VI-1 and VI-2.

	CHECK POINT	FUNCTION	TEST LIMITS
1.	CR201 Bridge output (Jct. C201-R201)	Positive raw dc output	34.5 to 37.5 V dc
2.	Cathode, CR203	Pre-regulator voltage	22.0 to 26.0 V dc
3.	Q201 collector-emitter	Current source reference	7.2 to 9.8 V dc
4.	Cathode, CR205	Regulated + dc output	8.6 to 9.6 V dc
5.	R222-R223 Jct.	Positive zero-ckt. source	0.105 to 0.120 V dc
6.	CR201 Bridge output (Jct. C202-R206)	Negative raw dc output	34.5 to 37.5 V dc
7.	Anode, CR204	Pre-regulator	22.0 to 26.0 V dc
8.	Q204 collector-emitter	Current source reference	7.2 to 9.8 V dc
9.	Anode, CR206	Regulated - dc output	8.6 to 9.6 V dc
10.	R224-R225 Jct.	Negative zero-ckt. source	0.105 to 0.120 V dc

Table VI-1. LOW VOLTAGE SUPPLY (Mother Board)
NOTE: Ground reference is case ground

(2) Monitor the positive side of the Low Voltage supply, and connect a short circuit from the supply to CASE GROUND. Upon removal of the short, the voltage must return to within the test limits; repeat for the negative side.

(3) Monitor the positive side of the High Voltage supply, and connect a short circuit to its ground reference (REC. OUTPUT +). Upon removal of the short, the voltage must return to within the limits; repeat for the negative side.

(4) The Model 134 power supplies are properly working if the test limits and short-circuit tests have been met.

6.5 AMPLIFIER BOARD

(1) Set the Model 134 controls as follows.

CHECK POINT	FUNCTION	TEST LIMITS
1. CR202 Bridge output (Jct. C203-R209)	Positive raw dc output	200 to 210 V dc
2. R209-R210 Jct.	Pre-filtered dc	169 to 181 V dc
3. Q207 base	Amplifier output	160 to 170 V dc
4. Cathode, CR207	Regulated positive high voltage output	110 to 130 V dc
5. CR202 Bridge output (Jct. C204-R216)	Negative raw dc output	200 to 210 V dc
6. R216-R217 Jct.	Pre-filtered dc	169 to 181 V dc
7. Q210 base	Amplifier output	160 to 170 V dc
8. Anode, CR208	Regulated negative high voltage output	110 to 130 V dc

Table VI-2. HIGH VOLTAGE SUPPLY (Mother Board)
NOTE: Ground reference is REC. OUTPUT (+)

Meter Function ---------- METER OFF
Mode ---------- FEEDBACK
Zero Check ---------- LOCKED
Range Multiplier ---------- 10 V
Range switch ---------- V

Use the M7000A Digital Voltmeter to monitor the REC. OUTPUT, and increase the Model 134 sensitivity with the RANGE MULTIPLIER. Establish a good zero at the Model 134 output with the Range Multiplier set to .001.

(2) After establishing a zero, reset the RANGE MULTIPLIER to 10. Using the M7000A Digital Voltmeter, with ground reference being the Model 134 CASE GROUND, check for proper operating voltages as outlined in Table VI-3.

(3) The Model 134 Amplifier Board is properly working if the test limits have been met.

6.6 INPUT BOARD

(1) Using the M7000A Digital Voltmeter connected with the Model 134 CASE GROUND as ground reference, measure the Q101 SOURCE/SUBSTRATE VOLTAGE at either of the following circuit points:

PIN #2, INPUT BOARD
Q103 collector, AMPLIFIER BOARD

CHECK POINT	FUNCTION	TEST LIMITS
1. R101-R105 common	Positive low voltage supply	8.6 to 9.6 V dc
2. R103-R104-R111 common	Negative low voltage supply	8.6 to 9.6 V dc
3. Q103 emitter	Input current source	7.1 to 8.1 V dc
4. Q104, Q105 emitters	Input stage operation	0 to -1.1 V dc
5. Q106 collector (+) to Q107 collector (-)	Second stage operation	+0.9 to +1.1 V dc
6. Q111 collector	Output gain switch operation	-1.0 to -1.2 V dc
7. Q113 emitter	Output follower operation	-0.4 to -0.7 V dc

Table VI-3. AMPLIFIER BOARD

The measured SOURCE/SUBSTRATE VOLTAGE test limits must be within +2.4 to +4.1 V dc.

(2) Measure the OFFSET VOLTAGE of the input MOS device at any of the following circuit points.

PIN #3, INPUT BOARD
C207 (gate side), MOTHER BOARD

The measured OFFSET VOLTAGE must not exceed 50 mV. The polarity may be either positive or negative. NOTE: BEFORE MEASURING THE INPUT OFFSET VOLTAGE, MAKE SURE THE MODEL 134 ZERO HAS BEEN ESTABLISHED.

(3) The Model 134 input board circuit is working properly if the test limits have been met.

6.7 CALIBRATION

The following adjustments constitute calibration of the Model 134. Set the operating controls as follows.

Meter Function ---------- +
Mode ---------- SHUNT
Zero Check ---------- LOCKED
Range Multiplier ---------- 1 V
Range switch ---------- V

6.7A BIAS ADJUST

Establish zero as previously described. Then reset the Range Multiplier to 1 V. Monitor the voltage drop across resistor R228 on the mother board, and

adjust R226 (Bias Control) for a nominal reading of 50 mV. The reading may be in the range of -5 to +10 mV of nominal and still be acceptable.

6.7B METER CALIBRATE

Apply 1.000 V (taken from precision voltage source) to the input of the Model 134. Release the Zero check. Using the mirrored meter scale to eliminate parallax (viewing pointer for absence of reflection), adjust R233 (METER CAL) so that the meter reads exactly 1.

6.7C ZERO CENTER CALIBRATE

Lock the Zero Check switch and set the Meter Function switch to ZERO CT. The meter pointer will advance up-scale. Adjust R230 (ZERO CT. CAL) so that the meter reads exactly 0 on the 5-0-5 meter scale.

6.7D R-CALIBRATE

Set the Range switch to the R (ohms) 10^5 position. Short circuit the input to case ground and release the Zero Check switch. With the M7000A Digital Voltmeter (XI OUTPUT as the ground reference), monitor the low resistance side of the Range switch (jumper on PC side, deck to deck). Adjust R219 (R-CAL) to read nominally +0.997 V. Switch the Range to 10^6. Observe that the reading does not exceed nominal 1.003 V. If required, adjust R-Cal such that readings do not differ by more than 0.005 V, and each does not exceed 1.000 ±0.007 V.

The Model 134 is now properly calibrated if the test limits have been met. The balance of the calibration-test procedure is concerned with meeting or exceeding specifications.

6.8 SPECIFICATIONS TESTS

The following procedures, outlined in Tables VI-4 through VI-8, should be performed in the order indicated.

6.9 FINAL TEST

6.9A METER/OUTPUT NOISE

Set the Model 134 controls as follows.

Meter Function	ZERO CT.
Mode	SHUNT
Zero Check	LOCKED
Range Multiplier	.001 V
Range switch	V
1 V/1 mA switch	1 V

Connect the Model 680 Chart Recorder to the REC. OUT terminals. Set the sensitivity and speed to 500 mV full scale and 8 in/hr. respectively. Zero the Model 134 as required. The recorder sensitivity, relative to the input of the Model 134, is now 500 μV full-scale. Observe that the peak-to-peak noise

TEST FUNCTION	SET CONTROLS	INPUT CONDITION	OPERATION	TEST LIMITS
(1) ZERO RANGE	METER FUNCTION: METER OFF MODE: SHUNT ZERO CHECK: LOCKED RANGE MULT: 1 VOLT RANGE: V	No Input	Check Voltage of each switch position at REC. OUT with M7000A Digital Voltmeter	19.0 to 24.0 mV per step
(2) COARSE ZERO	As above, except: RANGE MULT: .1 VOLT	As in #1	As in #1	20.0 to 25.0 mV per step
(3) FINE ZERO	As in #1, except: RANGE MULT: .01 VOLT	As in #1	Check voltage span of 10-turn FINE ZERO	400 to 850 mV
(4) CROSSOVER DISTORTION	METER FUNCTION: METER OFF MODE: SHUNT ZERO CHECK: LOCKED RANGE MULT: .001 RANGE SWITCH: V	Apply 1.5 kHz sine wave and release zero check, to give output of 1 V pk-pk	Monitor REC. OUT with scope	Observe for zero sine wave distortion. If required, adjust BIAS R226 for zero distortion
(5) XI SHORT CIRCUIT TEST	METER FUNCTION: + MODE: SHUNT ZERO CHECK: LOCKED RANGE MULT: 100 RANGE SWITCH: V	Apply +100 volts from precision voltage source	Release ZERO CHECK. Meter will read 1. Apply short circuit from UNITY GAIN to GUARD for 10-20 sec.	After removal of short circuit, observe that meter returns to 1
		Apply -100 volts	Repeat, reading meter with METER FUNCTION at '-'	As above
(6) REC. OUT LIMITS	METER FUNCTION: METER OFF MODE: SHUNT ZERO CHECK: LOCKED RANGE MULT: 1 RANGE SWITCH: V	Apply ±1 volt from precision voltage source	Release ZERO CHECK and monitor REC. OUT with M7000A Digital Voltmeter. Increase input voltage until output voltage reaches limiting value. Repeat for negative input	2.0 to 3.2 volts
(7) OUTPUT RIPPLE	As in #6	No input	Read Ripple pk-pk at REC. OUT with scope	10 mV pk-pk maximum

Table VI-4. GENERAL SPECIFICATIONS CHECKS

Table VI-4. GENERAL SPECIFICATIONS CHECKS (cont'd)

TEST FUNCTION	SET CONTROLS	INPUT CONDITION	OPERATION	TEST LIMITS
(8) FREQUENCY RESPONSE	METER FUNCTION: METER OFF MODE: SHUNT ZERO CHECK: LOCKED RANGE MULT: .001 RANGE SWITCH: V	Apply 20 Hz sine-wave. Advance frequency to 1.2 kHz	Release ZERO CHECK, monitor REC. OUT with M320A True RMS Meter. Adjust input such that output is 300 mV at 20 Hz. Advance to 1.2 kHz	MINIMUM 210 mV rms at 1.2 kHz
	As above except: RANGE MULT: .3	As above	As above except advance to 2.5 kHz	MINIMUM 210 mV rms at 2.5 kHz
(9) OUTPUT NOISE	A) METER FUNC: METER OFF MODE: SHUNT ZERO CHECK: LOCKED RANGE MULT: .001 RANGE SW: V	A) No input	A) Monitor REC. OUT with M320A True RMS Meter, set on 30 mV range	A) 20 mV MAXIMUM
	B) As above, except: RANGE MULT: .1	B) As above	B) Monitor REC. OUT with M320A True RMS Meter set on 10 mV range	B) 5 mV MAXIMUM
(10) 1 mA REC. OUT	METER FUNCTION: METER OFF MODE: SHUNT ZERO CHECK: LOCKED RANGE MULT: 1 RANGE SWITCH: V 1 V/1 mA SW: 1 mA	Apply 1 volt from precision voltage source	Place 1000 ohm (.1%) resistor across REC. OUT. Monitor with M7000A Digital Voltmeter. Release ZERO CHECK. Adjust 1 mA ADJ. and read output	Observe for 10% output variation with span of 1 mA ADJ.

TEST FUNCTION	SET CONTROLS	INPUT CONDITION	OPERATION	TEST LIMITS
(1) LINEARITY/ TRACKING	METER FUNCTION: + MODE: SHUNT ZERO CHECK: LOCKED RANGE MULT: 1 RANGE SWITCH: V 1 V/1 mA SW: 1 V	Apply +1.000 volt from precision voltage source Repeat for negative input	Release ZERO CHECK. Read meter and monitor REC. OUT with M7000A Digital Voltmeter. Check for 0.1 volt increments to 1.0 V Repeat for negative input	A) For 1.000 volt input, output must read within 0.5% or 0.995 to 1.005 volts B) For each increment (.9, .8, .7, etc.), output must read within 0.5% of input C) M134 meter must read within one minor division (±1%) for all input values Repeat for negative input
(2) ACCURACY	METER FUNCTION: + MODE: SHUNT ZERO CHECK: LOCKED RANGE MULT: 100, 30, 10, etc. RANGE SWITCH: V	A) Apply 100.00 volts from precision voltage source B) Repeat for all ranges (30, 10, 3, etc. to .001)	A) Release ZERO CHECK. Read meter and monitor REC. OUT with M7000A Digital Voltmeter B) As above	A) Meter must read within one minor division (±1%). Output must read 0.995 to 1.005 volts B) As above NOTE: Establish adequate zero for RANGE MULTIPLIER of .03 and below. Error on .01 and below will be observed within noise limits.
(3) 100 VOLT OVERRANGE	As in #2 except: RANGE MULT: 100	Apply +130 V to input Repeat for negative input	Release ZERO CHECK. Read REC. OUT.	Observe for minimum reading of 1.2 V

Table VI-5. VOLTMETER SPECIFICATIONS CHECKS

TEST FUNCTION	SET CONTROLS		INPUT CONDITION	OPERATION	TEST LIMITS
(1) OFFSET CURRENT	METER FUNCTION: MODE: ZERO CHECK: RANGE MULT: RANGE SWITCH:	ZERO CT. FEEDBACK LOCKED .01 10^{-12} (I)	CAPPED	Establish zero exactly. Release ZERO CHECK and observe that meter comes on scale	Read $\pm 3 \times 10^{-15}$ ampere on 5-0-5 scale MAXIMUM
(2) ACCURACY	METER FUNCTION: MODE: ZERO CHECK: RANGE MULT: RANGE SWITCH:	+ FEEDBACK LOCKED 1 10^{-6}, 10^{-7}, 10^{-8}, etc. (I)	Apply current with +1.000 volt in series with PAR standards, 10^6, 10^7, 10^8 ohms, etc.	Release ZERO CHECK and observe meter. Read REC. OUT with M7000A Digital Voltmeter	*10^{-6} : .980-1.020 10^{-7} : .980-1.020 10^{-8} : .980-1.020 10^{-9} : .980-1.020 10^{-10}: .980-1.020 10^{-11}: .980-1.020 10^{-12}: .960-1.040 On 10^{-11} and 10^{-12} ranges, error read is exclusive of offset current

*NOTE: Error limits are exclusive of high-megohm standard resistor limits of error.

Table VI-6. AMMETER SPECIFICATIONS CHECKS

TEST FUNCTION	SET CONTROLS	INPUT CONDITION	OPERATION	TEST LIMITS
(1) ACCURACY				
A) 10^5 OHM	A) METER FUNCTION: + MODE: SHUNT ZERO CHECK: LOCKED RANGE MULT: .1 RANGE SWITCH: 10^5 (R)	A) Connect 10 kΩ (.05%) across M134 input	A) Release ZERO CHECK. Read REC. OUT with M7000A Digital Voltmeter	**A) 0.970-1.030
B) 10^6 OHM	B) As above except: RANGE MULT: 1 RANGE SWITCH: 10^6 (R)	*B) Connect 10^6 ohm (.05%) or PAR 10^6 ohm stnd.	B) As above	B) 0.970-1.030
C) 10^7 OHM	C) As in #1A except: RANGE MULT: .1 RANGE SWITCH: 10^7 (R)	*C) As above	C) As in A	C) 0.970-1.030
D) 10^8-10^{10} OHM	D) As in #1A except: RANGE MULT: 1 RANGE SWITCH: 10^8, 10^9 10^{10} (R)	*D) Connect PAR stnd; 10^8, 10^9, 10^{10} for respective ranges	D) As in A	D) 10^8: 0.970-1.030 10^9: 0.970-1.030 10^{10}: 0.970-1.030
(2) ACCURACY				
A) 10^{11} OHM	A) METER FUNCTION: + MODE: FEEDBACK ZERO CHECK: LOCKED RANGE MULT: 1 RANGE SWITCH: 10^{11} (R)	A) Connect PAR 10^{11} ohm stnd. Return low side of stnd. to GUARD	A) Release ZERO CHECK. Read REC. OUT with M7000A Digital Voltmeter. Allow minimum of 1 minute for stabilization	A) 0.970-1.030
B) 10^{12} OHM	B) As above except: RANGE SWITCH: 10^{12} (R)	B) As above except with PAR 10^{12} ohm stnd.	B) As above, except allow 1.5 to 2 minutes for stabilization	B) 0.950-1.050

* NOTE: When using PAR standards (items B, C, D of Test Function 1), apply short circuit to BNC female end.
**NOTE: Error limits are exclusive of high-megohm standard resistor limits of error.

Table VI-7. OHMMETER SPECIFICATIONS CHECKS

TEST FUNCTION	SET CONTROLS	INPUT CONDITION	OPERATION	TEST LIMITS
(1) ACCURACY				
A) 10^{-7}	A) METER FUNCTION: + MODE: FEEDBACK ZERO CHECK: LOCKED RANGE MULT: 1 RANGE SWITCH: 10^{-7} (Q)	A) Apply current with 1.000 V in series with PAR 10^{8} ohm stnd.	A) Release ZERO CHECK and observe time required for meter to read full scale (1)	A) 9.5-10.5 sec.
B) 10^{-8}	B) As above except: RANGE SWITCH: 10^{-8} (Q)	B) As above except with PAR 10^{9} ohm stnd.	B) As above	B) As in A
C) 10^{-9}	C) As in A except: RANGE SWITCH: 10^{-9} (Q)	C) As in A except with PAR 10^{10} ohm stnd.	C) As in A	C) As in A
D) 10^{-10}	D) As in A except: RANGE MULT: 10 RANGE SWITCH: 10^{-10} (Q)	D) As in C	D) As in A	D) As in A

Table VI-8. COULOMBMETER SPECIFICATIONS CHECKS

does not exceed 30 μV on both the recorder (may differ if recorder is other than a Moseley M680) and the Model 134 panel meter.

6.9B VOLTAGE STABILITY

The Model 134 must be turned off for a period of two hours prior to the stability run. Set the controls as follows.

Meter Function	PWR. OFF
Mode	SHUNT
Zero Check	LOCKED
Range Multiplier	.001 V
Range switch	V
1 V/1 mA switch	1 V

After the Model 134 is off for two hours, turn it back on. Set the Meter Function switch to ZERO CT. and zero the instrument. The drift must be read and recorded after one hour. At one hour, record the drift and re-zero the electrometer. Allow the Model 134 to run for an additional 24 hours and record the drift again, reading the Model 134 panel meter directly on the 5-0-5 scale (500-0-500 μV). The limits of test are as follows.

1st hour end	±500 μV MAXIMUM
24 hour end	±500 μV MAXIMUM

6.9C OFFSET CURRENT

Upon completion of the stability run, check the Model 134 offset current again. Set the controls as follows.

Meter Function	ZERO CT.
Mode	FEEDBACK
Zero Check	LOCKED
Range Multiplier	.01 V
Range switch	10^{-12}

Establish zero exactly. Release the Zero Check switch and observe that the meter comes on scale. Read the offset current on the 5-0-5 scale (±5 x 10^{-15} A). The offset current must not exceed ±3 x 10^{-15} ampere.

SECTION VII
TROUBLESHOOTING

7.1 INTRODUCTION

Although the Model 134 Electrometer is a highly reliable instrument, component deterioration or failure could cause the instrument to no longer meet specifications, or even to become inoperative. By following the troubleshooting procedure in the order outlined, a person only slightly familiar with the operation of the Model 134 should be able to isolate the problem to a specific circuit section or component.

Once the malfunctioning circuit section or component is located, the user should contact Princeton Applied Research Corporation for advice on the relative merits of repairing the instrument himself or returning it (or a portion of same) to the factory for repair or replacement.

The troubleshooting procedure is designed to aid the operator in repairing the instrument, should he be advised to do so from the standpoint of cost, convenience, and instrument down time. It is advisable that the person performing the troubleshooting procedure and/or effecting repairs familiarize himself with Section III, GENERAL OPERATING CONSIDERATIONS, and with Section VI, ALIGNMENT PROCEDURE. These sections provide valuable information which may simplify repair of the Model 134 and restoration of the instrument to its original condition relative to the electrical specifications.

In troubleshooting, the operator should refer to the schematics and parts location diagrams in Section IX. The photographs with 'callouts' in Section VI may prove useful as well.

7.2 PRELIMINARY CONSIDERATIONS

7.2A INPUT BOARD (page IX-4)

When the need to troubleshoot the Model 134 arises, the user is advised to initially proceed on the assumption that the input stage is operating properly and to carry out the isolation procedures outlined further on in this section (Subsection 7.3 and following material). After completion of the procedure, or that portion required to isolate the problem, the input circuitry should be checked. Common symptoms and causes, indicative of input circuit malfunctioning, are outlined in Table VII-1.

If replacement of the input transistor Q101 or protective device Q102 is required, the user is advised to secure an entire replacement input board from PAR by ordering PAR part number 1340-2200-010. The replacement board is fully tested, and, when installed properly, will restore the Model 134 to its original specifications.

When replacing the input board, the user must take care with respect to static charge buildup when inserting the board into its mating connector. The gate of the MOS device used for zero suppression, unlike the input gate, is unprotected. Remove the shorting bar only while grounding oneself to the

SYMPTOM	PROBABLE CAUSE
(1) Excessive input offset current.	Defective input MOS device, Q101, or contamination.
(2) Excessive meter noise.	Defective input MOS device, Q101.
(3) High offset in ammeter modes, 10^{-6} to 10^{-10} amperes.	Defective input MOS device, Q101, or defective protective device, Q102.
(4) Excessive voltage drift with time and/or temperature.	Defective input MOS device, Q101.
(5) Excessive current noise and instability.	Defective or contaminated input device, Q101, or defective protective device, Q102.

Table VII-1. INPUT BOARD MALFUNCTIONS

electrometer and insert the new board while maintaining contact with the electrometer. Even before removing the shorting bar, it is advisable to place a small piece of aluminum foil over the tape side of the input board, thus shorting the unprotected gate to other circuit points. Once the board is installed, the foil can be removed. With the board installed, adequate protection is furnished by the shunting effects of other Model 134 circuitry.

After installation, the board should be cleaned to remove residual contamination. Use clean Q-tips and methanol (or clean Freon) for cleaning. Allow the solvent to rinse over the MOS and protective devices and surfaces by applying moderate pressure with a saturated Q tip. Generally, a rinsing action is all that will be required.

When re-wiring the input/bus/resistor to the input board, use no more solder than is necessary to make a good connection. Do not allow the solder fumes to drift onto or in the immediate vicinity of the input MOS device as vapor condensation will contaminate the circuitry.

7.2B RANGE SWITCH (Page IX-2)

The Range switch, S306, is designed to give trouble-free service for more than 100,000 operations. The contact pressure of the high-resistance contactor assembly has been pre-set at the factory for long contact life and minimum transient operation. Do not attempt to readjust, remove, or replace any portion of the Range switch. Should a problem with the switch be suspected, the instrument should be returned to the factory for repair.

Periodic cleaning of the high-resistance contactor assembly may be necessary. Clean gently as previously recommended. Do not flex the contactor unneces-

sarily, as the proper tension may be altered, giving rise to faulty switching operation and transient behavior.

7.2C ZERO CHECK SWITCH (page IX-2)

The Zero Check switch, S304, has been designed to give in excess of 100,000 troublefree operations. As with the Range switch, the contactor pressure has been preset at the factory and the instrument should be returned to the factory for repair or replacement if a problem is suspected.

Periodic cleaning of the Zero Check switch may be necessary. Clean gently as previously recommended. When cleaning the switch, it is advisable to keep it in the LOCKED position to prevent possible flexing of the contactor mechanism.

7.2D HIGH-MEGOHM RESISTORS (page IX-2)

The high-megohm resistors, mounted on the Range switch, should require little or no service. These resistors have been aged, tested, and selected for high accuracy and for favorable voltage and temperature coefficient performance. However, it could happen that after a period of 18-24 months, the operator may find that the ammeter and ohmmeter accuracies have degraded. This is normal, being a function of the drift of the nominal resistor value as a function of time. If the inaccuracies are not tolerable, the resistors should be replaced. Replacement resistors should only be obtained from PAR, as they will have been properly aged and tested for use in the Model 134. The following PAR part numbers are given for convenience in obtaining replacements.

VALUE	PAR PART NUMBER
10^7 ohms	4741-0051-04
10^8 ohms	4741-0052-03
10^9 ohms	4741-0053-02
10^{10} ohms	4741-0054-01
10^{11} ohms	4741-0055-00
10^{12} ohms	4741-0056-09

Note that the nominal resistance value decreases with time, giving an indication of resistor contamination. Symptoms of both resistor drift and contamination are as follows.

(1) When operated as an ammeter, the Model 134 reads consistently low in measured and observed readings.

(2) When operated as an ohmmeter, the Model 134 will indicate consistently high in measured and observed readings.

If it is necessary to replace high-megohm resistors, do not touch the body of one of these resistors during installation. Handle them only by the leads, and flex the leads no more than absolutely necessary. A 'clip-on' heat sink is recommended during soldering, and one should take care to apply no more heat than is needed. Be sure the replacement resistor is installed in exactly the same position as was occupied by the original resistor.

Further, do not clean high-megohm resistors unless all other error sources have been eliminated. If they must be cleaned, observe the precautions outlined in Subsection 3.3G (page III-10).

7.3 EQUIPMENT NEEDED

The only special piece of equipment required to troubleshoot the Model 134 is a general purpose digital voltmeter having an input resistance of at least ten megohms and a resolution of 1 mV. The Fairchild Model 7000A, or equivalent instrument, is recommended.

7.4 POWER SUPPLY CHECKS

(1) Remove the top and bottom covers of the Model 134.

(2) Looking at the instrument from above, note the two flex-ribbon cables that extend from the Amplifier board to the Mother board. Disconnect these cables by unplugging them at the Mother board.

(3) Set the Model 134 controls as follows.

Meter Function ---------- PWR OFF
Mode ---------- FEEDBACK
Zero Check ---------- LOCKED
Range Multiplier ---------- 1
Range ---------- V

(4) Plug in the line cord and set the Meter Function switch to '+'. The meter should remain at '0'.

(5) Tables VII-2 and VII-3 outline the check points, functions, test limits, and test limit failure causes for the power supplies. The procedure should be followed in the sequence given. Ground reference for the voltage measurements is the Model 134 case ground. The schematic of the Power Supply circuitry is on page IX-3.

CHECK POINT	FUNCTION	TEST LIMITS	PROBABLE FAULTY COMPONENT
(1) CR201 Bridge output (Jct C201-R201).	Positive raw dc output.	+34.5 V to +37.5 V	CR201 bridge rectifier, transformer T201, or capacitor C201.
(2) Cathode, CR203.	Pre-regulator voltage.	+22.0 V to +26.0 V	CR203, R201
(3) Q201 collector-emitter.	Current source reference.	7.2 V to 9.8 V	Q201, R202
(4) Base, Q203.	Current reg. voltage.	+9.0 V to +14.5 V	Q202, Q203, R203, or R204.
(5) Cathode, CR205.	Regulated + dc output.	+8.6 V to +9.6 V	Q203, CR205, or C208.
(6) CR201 Bridge output (Jct C202-R206).	Negative raw dc output.	-34.5 V to -37.5 V	CR201 bridge rectifier, transformer T201, or capacitor C202.
(7) Anode, CR204.	Pre-regulator.	-22.0 V to -26.0 V	CR204 or R206.
(8) Q204 collector-emitter.	Current source reference.	7.2 V to 9.8 V	Q204 or R207.
(9) Base, Q206.	Current reg. voltage.	-9.0 V to -14.5 V	Q205, Q206, R208, or R205.

Table VII-2. LOW-VOLTAGE SUPPLY CHECKS

CHECK POINT	FUNCTION	TEST LIMITS	PROBABLE FAULTY COMPONENT
(1) CR202 Bridge ouput (Jct C203-R209).	Positive raw dc output.	+200 V to +210 V	CR202, T201, or C203.
(2) R209-R210 jct.	Prefiltered dc.	+169 V to +181 V	C205 or R209
(3) Q207 base.	Amplifier output.	+160 V to +170 V	Q207, Q208, or R210-213.
(4) Cathode, CR207.	Regulated + output.	+110 V to +130 V	Q207, CR207, or C210.
(5) CR202 Bridge output (Jct C204-R216).	Negative raw dc output.	-200 V to -210 V	CR202, transformer T201, or C204.
(6) Jct of R216-R217.	Prefiltered dc.	-169 V to -181 V	C206 or R216.
(7) Base of Q210.	Amplifier output.	-160 V to -170 V	Q209, Q210, R214, R215, R217, or R218.
(8) Anode of CR208.	Regulated - output.	-110 V to -130 V	Q210, CR208, or C211.

Table VII-3. HIGH-VOLTAGE SUPPLY CHECKS

(6) If no problems are found in the power supply checks, proceed to Subsection 7.5, which follows.

7.5 ZERO ADJUST CIRCUITRY (schematics on pages IX-2 and IX-3)

(1) Monitor the junction of resistors R222 and R223 (located on the Mother board). The monitored voltage should be in the range of +0.105 V to +0.120 V.

(2) Monitor the junction of resistors R224 and R225 (located on the Mother board). The monitored voltage should be in the range of -0.105 V to -0.120 V.

(3) Reconnect the ribbon cables disconnected earlier in step 2 of Subsection 7.4.

(4) Monitor the gate side of capacitor C207 on the Mother board. Check the Zero controls (Fine Zero, Coarse Zero, and Zero Range) for their influence on the voltage at the monitor point (C207). The voltage should vary as follows.

Fine Zero ---------- 4.0 mV - 8.5 mV total span.
Coarse Zero ---------- 2.0 mV - 2.5 mV per step.
Zero Range ---------- 19 mV - 24 mV per step.

If the test limits are not met, check the following.

(a) Coarse Zero switch for flexing to front panel and contacting action.

(b) Fine Zero control for wiring integrity.

(c) Zero Range switch for wiring integrity.

(d) Coarse Zero resistor string, R130-R139.

(e) Zero Range resistor string, R314-R324.

(5) If, after checking the Zero Adjust circuitry, no problem is found, proceed to Subsection 7.6, which follows.

7.6 AMPLIFIER CHECKS (schematic on page IX-4)

(1) Turn off the Model 134 power. Then disable the feedback loop by removing output transistors Q211 and Q212, which are located on the Mother board. NOTE: Before these transistors can be removed, one must first remove the output shield located above the transistors.

(2) After disabling the feedback loop, each stage of the amplifier can be checked as follows.

(3) Turn the power back on. Then monitor the voltage across R101. The voltage should be in the range of 1.2 V to 1.8 V. Next monitor the source/substrate voltage (collector of Q103) of Q101. The voltage there should be in the range of +2.4 V to +4.1 V.

(4) Connect the digital voltmeter between the two drains of Q101, the input MOS device. Then verify that the Model 134 Zero controls enable the voltage reading to be nulled, and to pass through zero, plus and minus.

(5) If the Q101 drain-to-drain voltage does not pass through zero, remove the second stage, Q104 and Q105. If the required adjustment through zero can be achieved with these transistors removed, Q104 and Q105 are defective. If, however, the Q101 drain voltage still does not pass through zero, replace Q101 (by replacing the input board as described in Subsection 7.2A). Return Q104 and Q105 to the circuit.

(6) Check the second stage, Q104-Q105, by monitoring between the emitters of these transistors. Adjustment of the Zero controls will enable the voltage to pass through zero if Q104-Q105 and the third stages are functioning properly. If the voltage cannot be swung through zero, try removing Q106 and Q107. If the voltage now swings through zero, Q106 and/or Q107 are defective. If so, replace either or both of these transistors and proceed to check the remaining stages.

(7) Place the 'high' lead of the digital voltmeter on the collector of Q106. Connect the 'low' lead to the collector of Q107. Adjust the Zero controls and verify that the voltage can be made to swing through +1 V. If the collector-to-collector voltage does not pass through +1 V, remove Q108 and Q109 and repeat the check. If the voltage now passes through +1 V, Q108 and/or Q109 are defective. Replace either or both of these transistors as required.

(8) Monitor the collector of Q111, the final gain stage of the amplifier. The Zero adjustment will allow the collector voltage to swing through zero if Q110, Q111, Q112, and Q113 are functioning properly. If the collector voltage does not swing through zero, remove Q113 and repeat the check. If the collector now swings through zero, replace defective Q113. If, however, removal of Q113 does not correct the problem, check transistors Q110-Q112. Replace as required.

(9) If, after completing the 'stage-by-stage' checkout of the amplifier, including replacing any transistors as may have been required, the emitter voltage of Q113 is able to swing through zero, proceed to Subsection 7.7.

7.7 OUTPUT CIRCUIT CHECKS (schematic on page IX-3)

(1) Check output transistors Q211 and Q212 before returning them to the mother board.

(2) Install Q211 and Q212, thus restoring the feedback loop. If the amplifier, along with transistors Q211 and Q212 are now known to be good, the Model 134 should function properly, providing the balance of the circuitry is working correctly.

(3) If the Model 134 isn't working properly yet, check, in sequence, the following possibilities.

(a) CR210-213, R227, R228.

(b) Range Multiplier resistors R118-R128, and associated switching circuitry; also check for defective solder joints.

(c) Output circuit consisting of Meter Function switch, R232, R233, and R325; also check the associated 1 V - 1 mA switch circuit.

(d) Check for proper Zero circuit operation by monitoring the collector-to-emitter voltage of Q213. Limits of test are 7.2 to 9.8 V dc. Replace Q213 if required to restore the test limits and proper zero circuit operation.

NOTE: The voltage readings on the Model 134 schematics are nominal; the indicated test limits in this procedure take precedence.

7.8 FINAL CHECKS

It is desirable to perform a general check-out of the Model 134 while troubleshooting or as a final measure after repair. A suitable procedure for this purpose follows.

7.8A GENERAL PHYSICAL INSPECTION

NOTE: DO NOT TOUCH TEFLON SUFACES, HIGH-MEGOHM RESISTORS, OR POLYSTYRENE CAPACITORS, AS THEY ARE SUBJECT TO RESULTANT CONTAMINATION.

(1) Proper alignment of board mounted switches with respect to the front panel. Observe that improper flexing of the COARSE ZERO and RANGE MULTIPLIER switches does not occur.

(2) Mechanical integrity of concentric FINE ZERO adjustment; link from pot to inner shaft.

(3) Top support bars properly aligned with respect to rack-mounting capa-

bility (holes facing outward); proper rigid fastening to panels of top and bottom support bars.

(4) Observe that the METER FUNCTION switch is securely attached; also the ac line shield.

(5) Proper fastening and rigidity of the amplifier board to front panel, to Range switch shield, and to mother board.

(6) Observe that the front and rear panel wiring to the mother board is properly terminated.

NOTE: RELATIVE TO INSPECTION PROCEDURE OUTLINED, OBSERVE THAT ALL TEFLON SURFACES ARE FREE OF DUST, DIRT, AND SOLDER FLUX. TEFLON SUFACES, APPEARING SHINY TO THE EYE, REQUIRE CLEANING DUE TO SOLDER FLUX RESIDUE DEPOSITED BY VAPOR CONDENSATION DURING SOLDERING PROCEDURES. IF REQUIRED, CLEAN WITH Q-TIP AND CLEAN FREON SOLVENT.

NOTE: FREON MUST BE OBTAINED FROM A CLEAN SOURCE, AND CONTAINED IN A CLEAN FREON-RINSED GLASS BEAKER. USE EACH Q-TIP ONCE TO AVOID FREON CONTAMINATION.

7.8B HIGH-RESISTANCE/INPUT CIRCUITRY

(1) INPUT BOARD

(a) Observe that the Input Board is securely in place.

(b) Check for proper connection, via the 10 megohm resistor, to the Zero Check switch (pointed electrical contactor).

(c) Observe that no cotton fibers (from Q-Tip cleaning) are in the vicinity of the MOS device and protection diode on the Input board.

(2) ZERO CHECK SWITCH

(a) Check for non-binding action of the switch, and locking action: when locked, pointed contactor (high resistance leaf) should not be bent inward more than 1/8".

(b) Observe that no cotton fibers are adhering to the leaf contacts, solder areas, or Teflon standoffs of the switch.

(3) RANGE SWITCH

(a) Observe that the Teflon contactor surface distance from the contact plate is nominally 1/16".

(b) Observe that the contactor button (tip) lies exactly on the contact button.

(c) Observe that the input contact leaf (pointed contactor) properly touches the rotor surface (center of the flat surface). Also,

the input contact leaf should be angled, by rotor contactor pressure, toward the front panel nominally 1/16", or approximately 5°.

(d) Check for proper rotor contactor pressure upon buttons; check for contact on all buttons.

(e) Observe proper alignment; when the Range switch is in 'V', contactor lies on open button (no component soldered to this button).

(f) Observe that the two low-resistance decks (phenolic) are electrically connected with soldered connection.

(g) Check that no high-megohm resistors are touching each other; also observe same for clear polystyrene capacitors.

(h) Observe that the high-megohm resistors are clear and free or dirt and/or cloudy appearance.

(i) Check for an absence of flux on the contact button, Teflon surfaces, and solder joints.

(j) Observe that the 10^{12} ohm jumper (Teflon-covered) is not touching the contact plate surface.

(k) Observe that no cotton fibers are adhering to any soldered connections, Teflon surfaces, components, or wiring on, or in the vicinity of, the Range switch.

(4) INPUT CONNECTOR/WIRING

(a) Observe that the input bus wire is Teflon-covered.

(b) Check for an absence of flux on the soldered connection of the connector.

(c) Observe that no cotton fibers are adhering to the connector surface and soldered connection.

SECTION VIII
WARRANTY

Princeton Applied Research Corporation warrants each instrument of its own manufacture to be free from defects in material and workmanship. Obligations under this Warranty shall be limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned, shipment prepaid, to our factory for that purpose within ONE year of delivery to the original purchaser, provided prior authorization for such return has been given by an authorized representative of Princeton Applied Research Corporation.

This Warranty shall not apply to any instrument, which our inspection shall disclose to our satisfaction, to have become defective or unworkable due to abuse, mishandling, misuse, accident, alteration, negligence, improper installation, or other causes beyond our control. This Warranty likewise shall not apply to any instrument or component not manufactured by Princeton Applied Research Corporation. When products manufactured by others are included in Princeton Applied Research Corporation equipment, the original manufacturer's warranty is extended to Princeton Applied Research Corporation's customers.

Princeton Applied Research Corporation reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION ON THE FACE HEREOF. THIS WARRANTY IS IN LIEU OF, AND EXCLUDES ANY AND ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESSED, IMPLIED OR STATUTORY, INCLUDING MERCHANTABILITY AND FITNESS, AS WELL AS ANY AND ALL OTHER OBLIGATIONS OR LIABILITIES OF PRINCETON APPLIED RESEARCH CORPORATION, INCLUDING, BUT NOT LIMITED TO, SPECIAL OR CONSEQUENTIAL DAMAGES. NO PERSON, FIRM OR CORPORATION IS AUTHORIZED TO ASSUME FOR PRINCETON APPLIED RESEARCH CORPORATION ANY ADDITIONAL OBLIGATION OR LIABILITY NOT EXPRESSLY PROVIDED FOR HEREIN EXCEPT IN WRITING DULY EXECUTED BY AN OFFICER OF PRINCETON APPLIED RESEARCH CORPORATION.

SECTION IX
SCHEMATICS

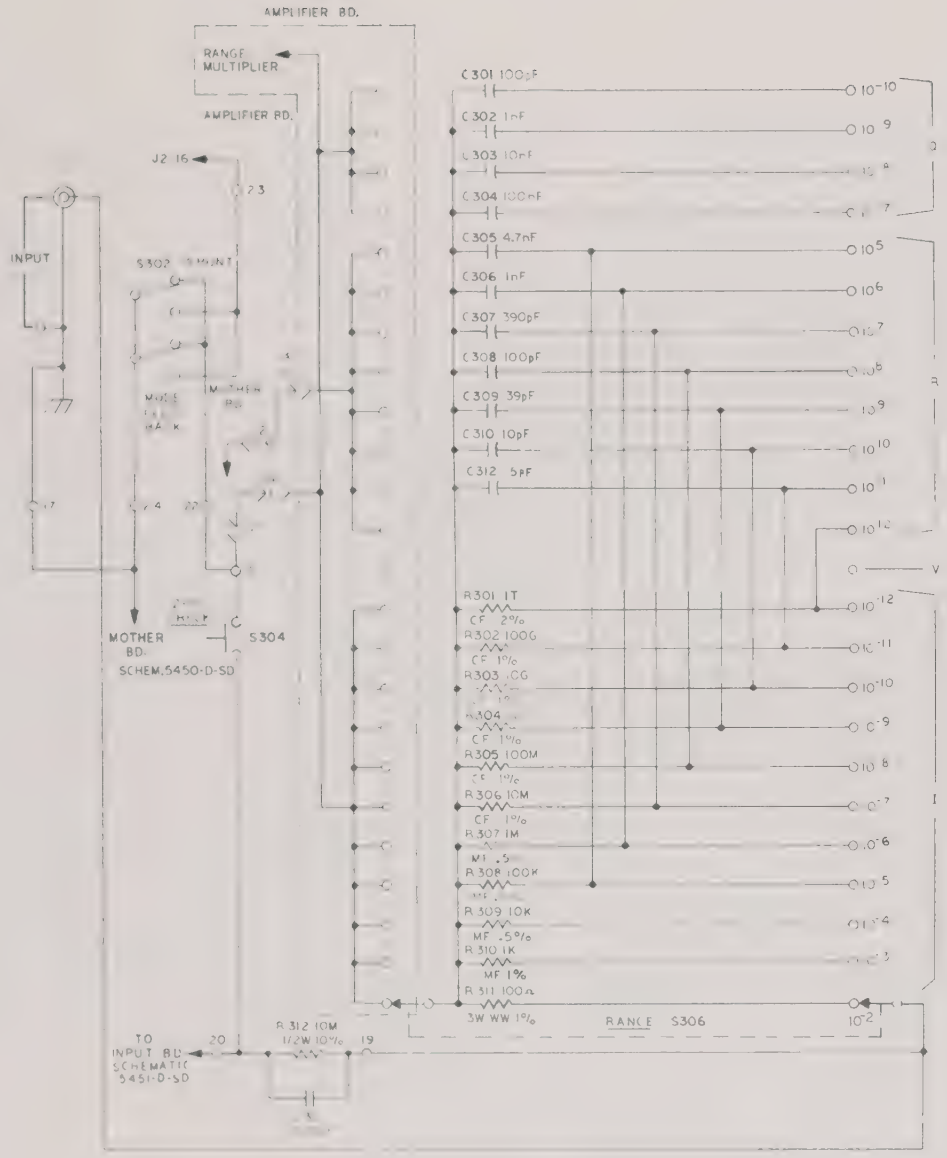
Page

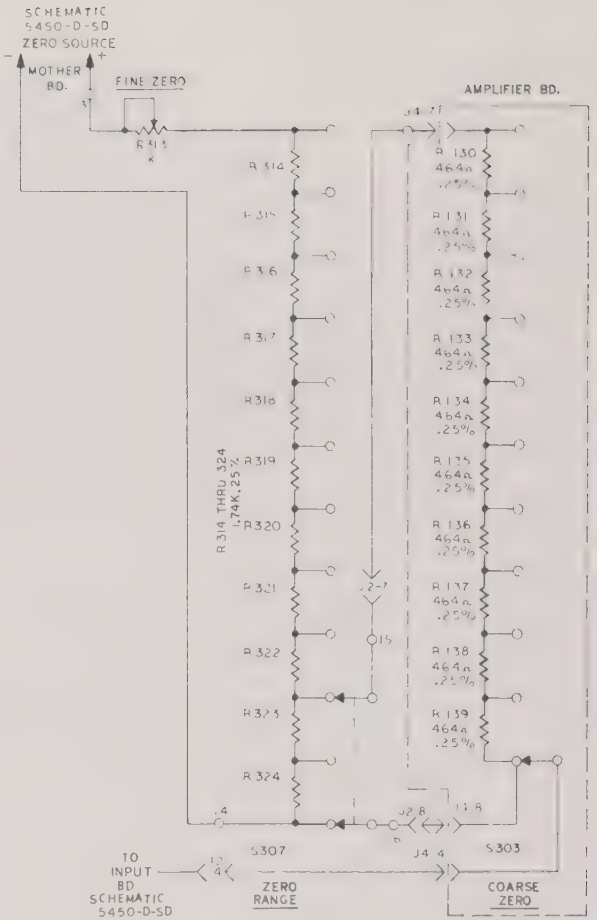
TABLE OF SCHEMATICS ---------- IX-1

INPUT SWITCHING (5452-C-SD) ---------- IX-2

MOTHER BOARD (5450-D-SD) ---------- IX-3

AMPLIFIER BOARD (5451-D-SD) ---------- IX-4





NOTES

1 — ALL .25% RESISTORS 1/2W METAL FILM.

2 ALL 300 SERIES COMPONENTS LOCATED ON FRONT OR REAR PANELS.

INPUT SWITCHING MODEL - 134

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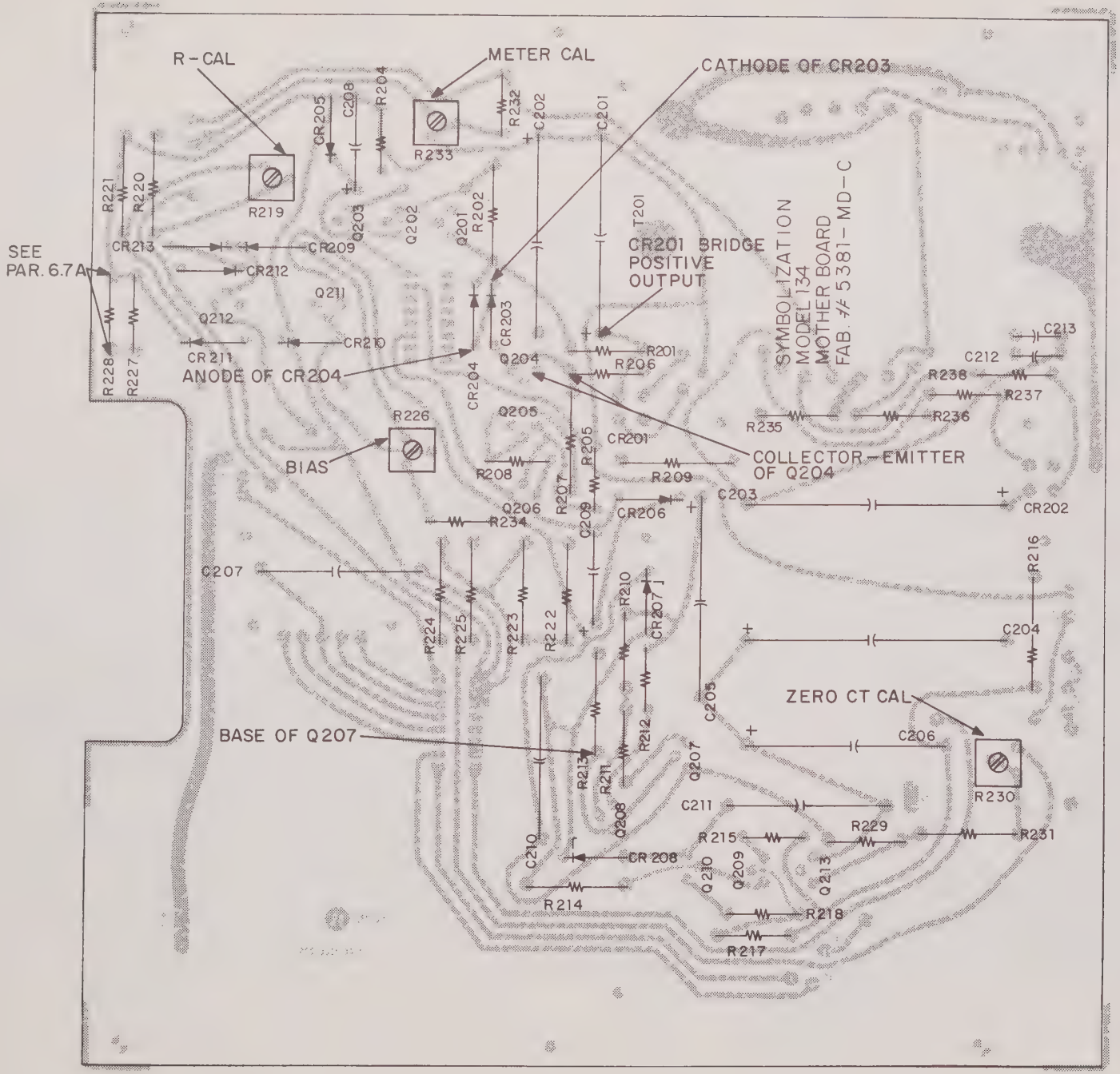
R-CAL
METER CAL
CATHODE OF CR203
SEE PAR. 6.7A
CR201 BRIDGE POSITIVE OUTPUT
SYMBOLIZATION MODEL 134 MOTHER BOARD FAB. # 5381-MD-C
ANODE OF CR204
BIAS
COLLECTOR-EMITTER OF Q204
BASE OF Q207
ZERO CT CAL
R219
R233
R226
R230
R232
R221
R220
R228
R227
R201
R202
R203
R204
R205
R206
R207
R208
R209
R210
R211
R212
R213
R214
R215
R216
R217
R218
R223
R224
R225
R229
R231
R234
R235
R236
R237
R238
C201
C202
C203
C204
C205
C206
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C212
C213
CR201
CR202
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CR204
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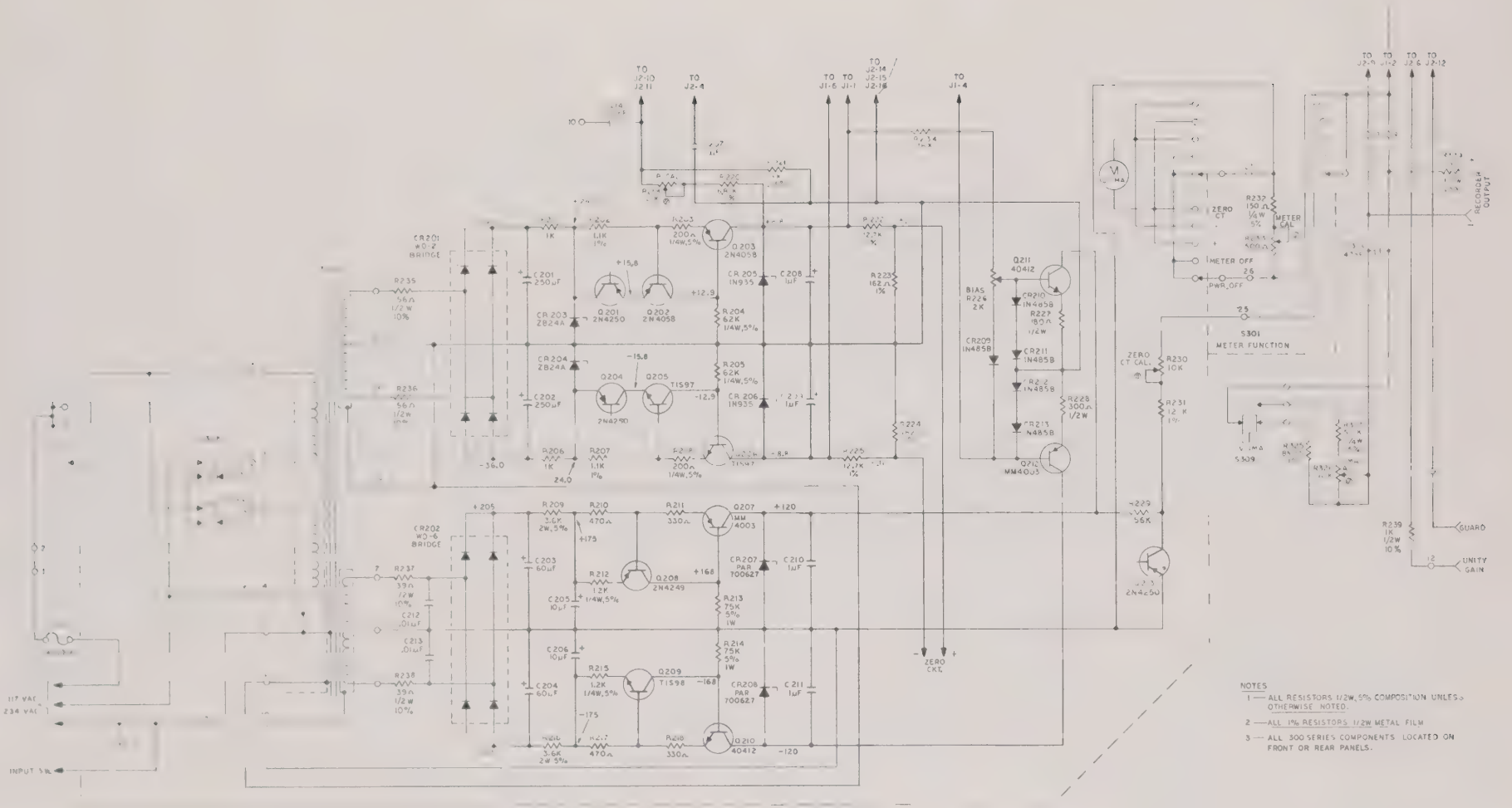
Q213
T201



NOTES

1 — ALL RESISTORS 1/2W, 5% COMPOSITION UNLESS OTHERWISE NOTED.

2 — ALL 1% RESISTORS 1/2W METAL FILM

3 — ALL 300 SERIES COMPONENTS LOCATED ON FRONT OR REAR PANELS.

MOTHER BD
MODEL-134

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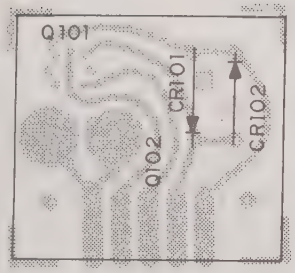
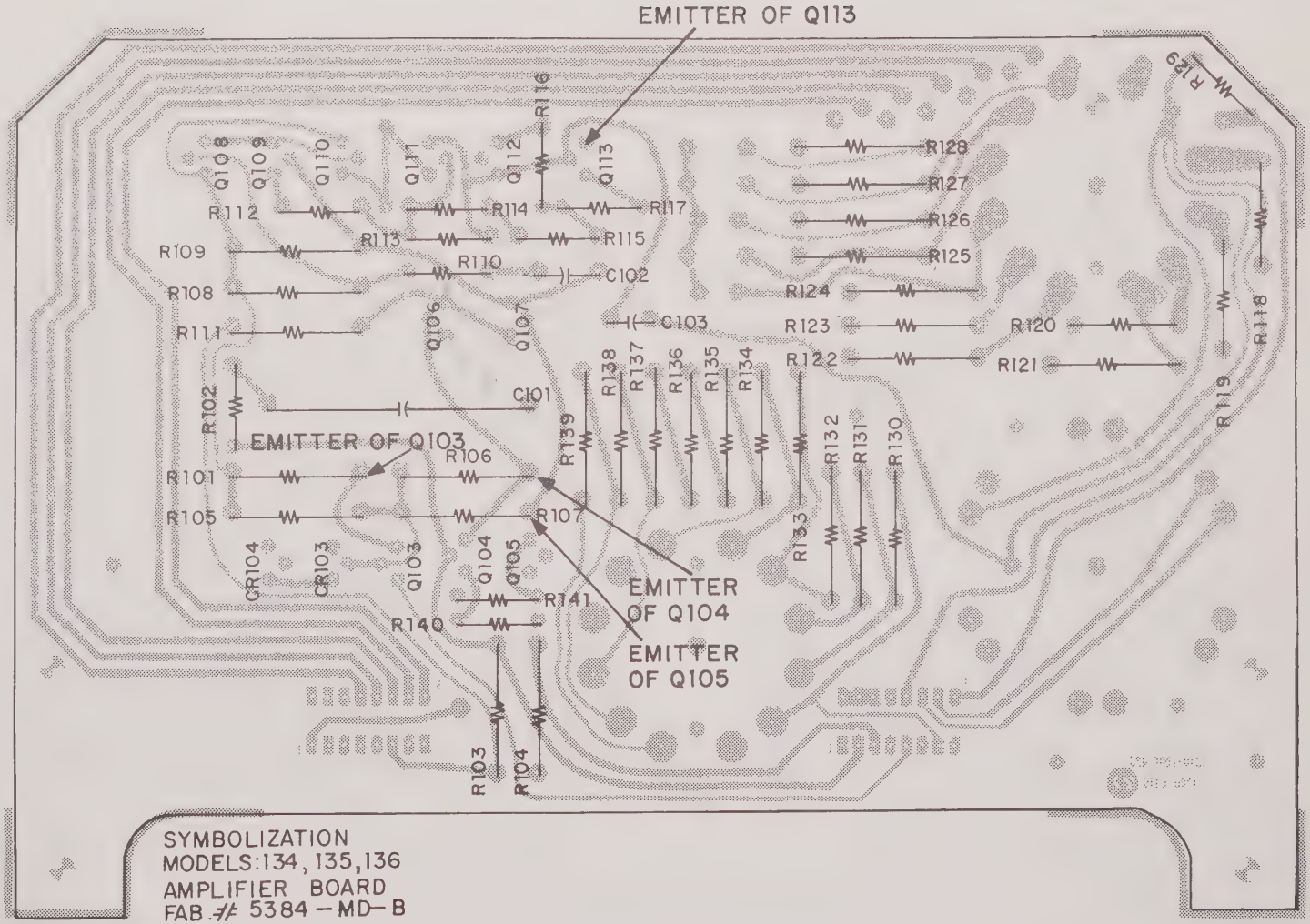
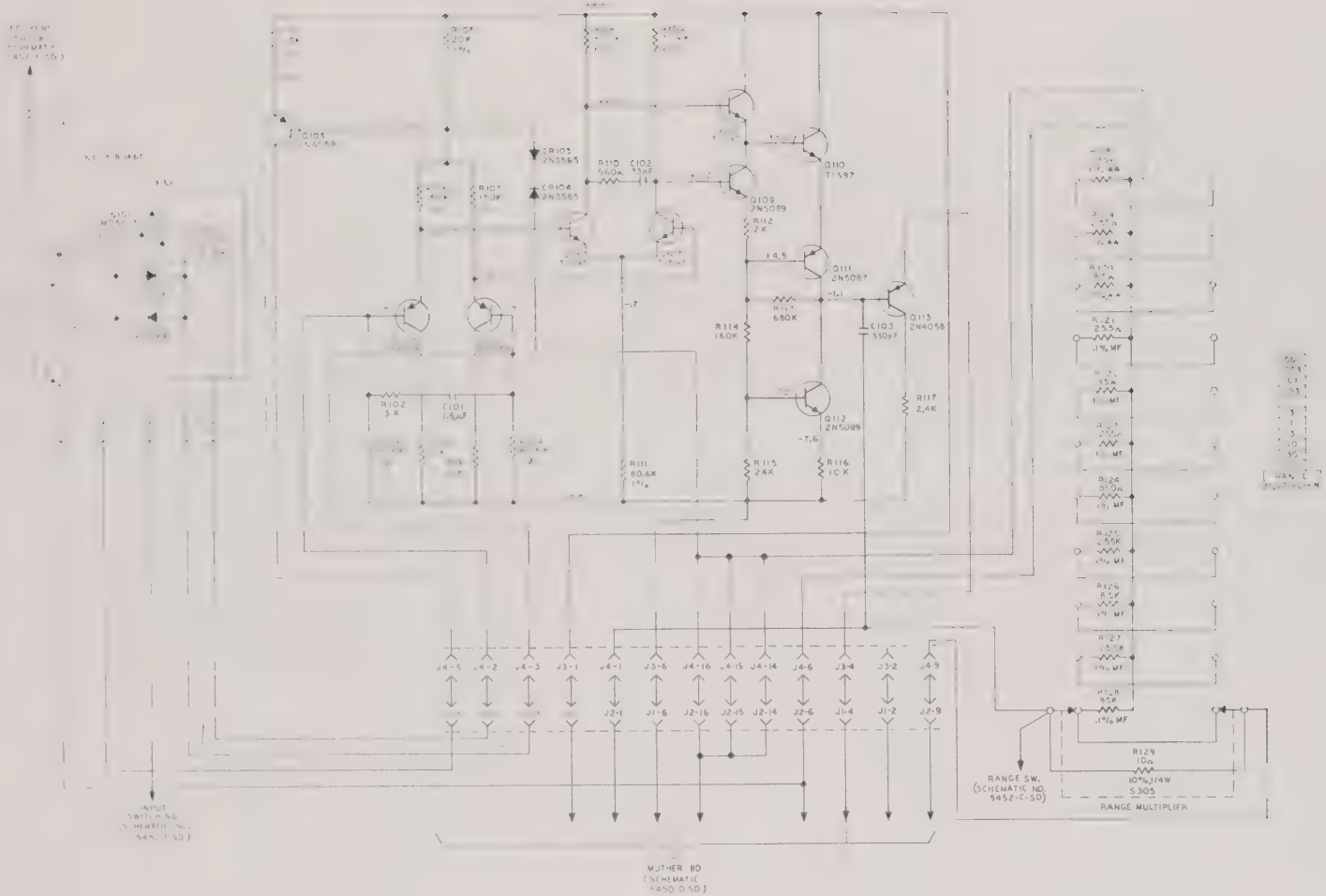


SYMBOLIZATION
MODELS 134, 135, 136
INPUT PLUG-IN BOARD
FAB. # 5387-B-MD-C



SYMBOLIZATION
MODELS:134, 135,136
AMPLIFIER BOARD
FAB.# 5384 — MD— B



AMPLIFIER BD
MODEL-134

NOTES:

1 - ALL RESISTORS 1/4W, 5% COMPOSITION UNLESS OTHERWISE NOTED.

2 - ALL 1% RESISTORS 1/2W METAL FILM.

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APPENDIX
OPTIONS AND ACCESSORIES

A.1 INTRODUCTION

This section of the manual discusses the options and accessories available for the Model 134. Characteristics, and where applicable, limitations of the options and accessories are considered. Should additional technical information be required, or information concerning the suitability of any option or accessory in a given application, the customer is advised to contact Princeton Applied Research Corporation directly.

The available options are obtained by modification of the standard Model 134 Electrometer. Any single option, or combination of options, can be built into an instrument. The accessories are separate product items to aid in using the Model 134, or, in the case of the 134/22 Input Board, to help necessitate repair.

A.2 OPTIONS

A.2A VOLTAGE STABILITY

The Model 134 may be ordered with improved dc voltage stability by specifying Option #134/96. With this option, the maximum dc drift, referred to the input, is 35 μV/°C and 350 μV/24 hr after a one-hour warmup. If requested, the customer will be furnished stability certification and the actual drift chart recordings for his instrument.

The Model 134 current drift, specified as 10^{-15} A/24 hr, will be improved by the ratio of the voltage stability improvement achieved, although no formal improved current stability specification is given for this option.

Figures A-1 and A-2 show actual typical measured temperature and time stability records of a production Model 134 having the 134/96 option installed. The improved voltage stability is achieved by stringent selection of the input MOS device.

A.2B VARIABLE DAMPING

The Model 134 can be ordered with variable damping, Option #134/97. This option permits the Model 134 rise time to be varied by means of a rear-panel screwdriver adjustment (single turn) when the instrument is being operated as an ammeter in the feedback mode. The range of adjustment is from the minimum specified for the Model 134 (or 'critical') to a maximum of 40 s, depending on the range selection, as shown in Table A-1.

If the Model 134 is being used in any but the ammeter mode of operation, the Damping control should be set to minimum (fully counterclockwise). Note that the input capacitance of the instrument, specified as 10 pF, is increased to 30 pF with the Variable Damping option installed.

Figure A-3 is a block diagram showing how the Variable Damping circuitry is

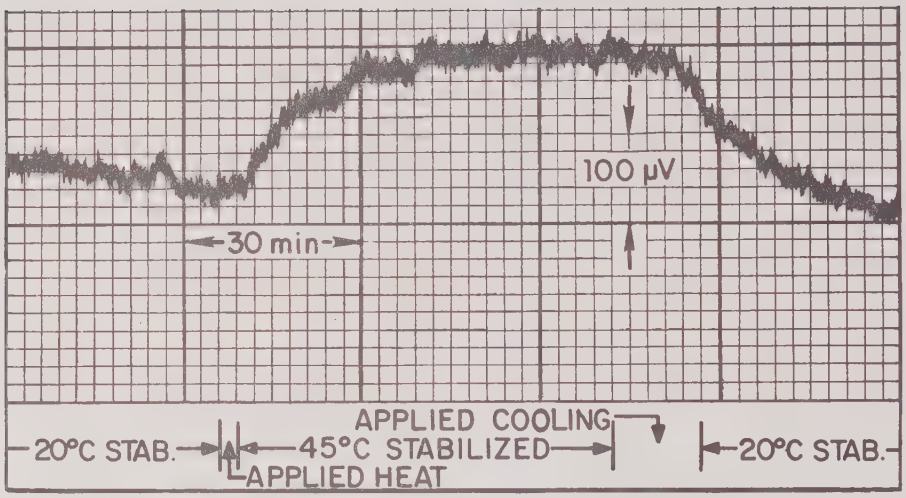

Figure A-1. MEASURED TEMPERATURE STABILITY ON PRODUCTION VOLTAGE STABILITY OPTION 134/96 -- NOTE THAT TEMPERATURE COEFFICIENT DOES NOT EXCEED 35 µV/°C

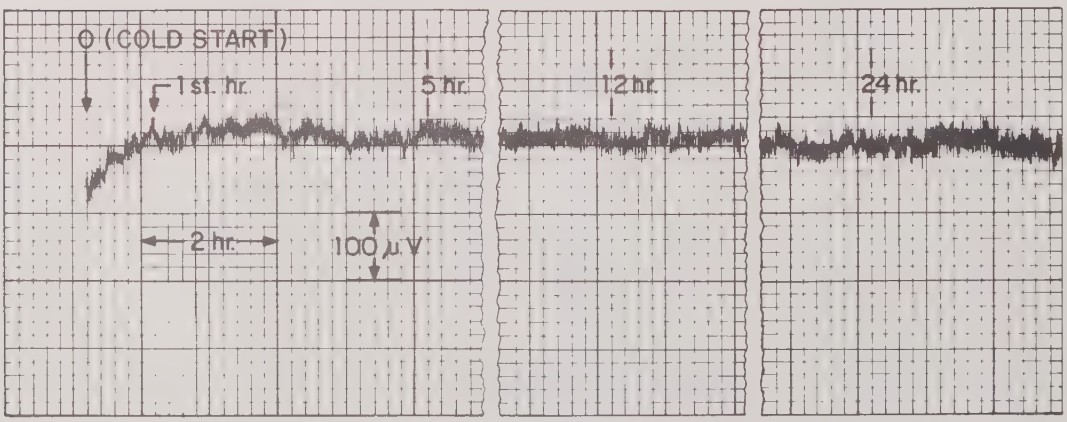

Figure A-2. MEASURED TIME STABILITY ON PRODUCTION VOLTAGE STABILITY OPTION 134/96 -- NOTE THAT DRIFT DOES NOT EXCEED 350 µV/24 HR AFTER ONE-HOUR WARMUP

Range Switch Setting	Minimum Rise Time In Seconds	Maximum Rise Time In Seconds
10^{-12}	5.0	40
10^{-11}	2.0	6.0
10^{-10}	0.3	.75
10^{-9}	0.1	.15
10^{-8} and above	0.03 to 0.003	Not Effective

Table A-1. VARIABLE RISE TIME RANGE AS A FUNCTION OF RANGE SWITCH SETTING

incorporated into the instrument for ammeter operation in the feedback mode.

NOTE: IF THE VARIABLE DAMPING OPTION IS INSTALLED IN ADDITION TO THE INPUT CURRENT SUPPRESSION OPTION, 134/99, THE MAXIMUM ATTAINABLE DAMPING IS AFFECTED, DEPENDENT ON THE RANGE OF INPUT CURRENT SUPPRESSION. FOR DETAILS, SEE SUBSECTION A.2D, INPUT CURRENT SUPPRESSION.

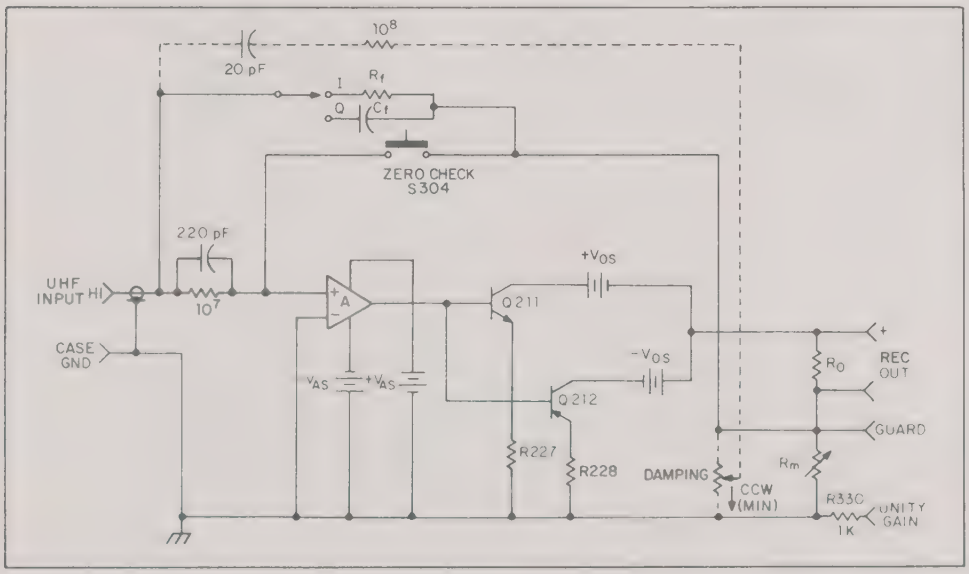

Figure A-3. MODEL 134 EQUIPPED WITH VARIABLE DAMPING OPTION

A.2C VARIABLE OHMS

The Variable Ohms Option, #134/98, allows the operator to continuously vary the constant current output when operating the Model 134 as an ohmmeter or constant current source. The control itself is a ten-turn screwdriver adjustment mounted on the rear panel. With it, the current output can be set anywhere between the selected decade steps of the Range switch (reciprocal of ohmmeter range being output constant current). Thus, operated in con-

junction with the Range switch, the adjustment permits continuous output constant current operation from 10^{-5} to 10^{-14} A.

The Range switch settings overlap the range of the ten-turn adjustment by a minimum of 2%. Model 134's having the 134/98 option installed leave the factory with the adjustment set for standard ohmmeter operation.

Figure A-4 is a block diagram showing how the Ohms Adjust control is incorporated into the instrument in the shunt ohmmeter mode of operation. Operation as a feedback ohmmeter/current source is also possible with the option installed.

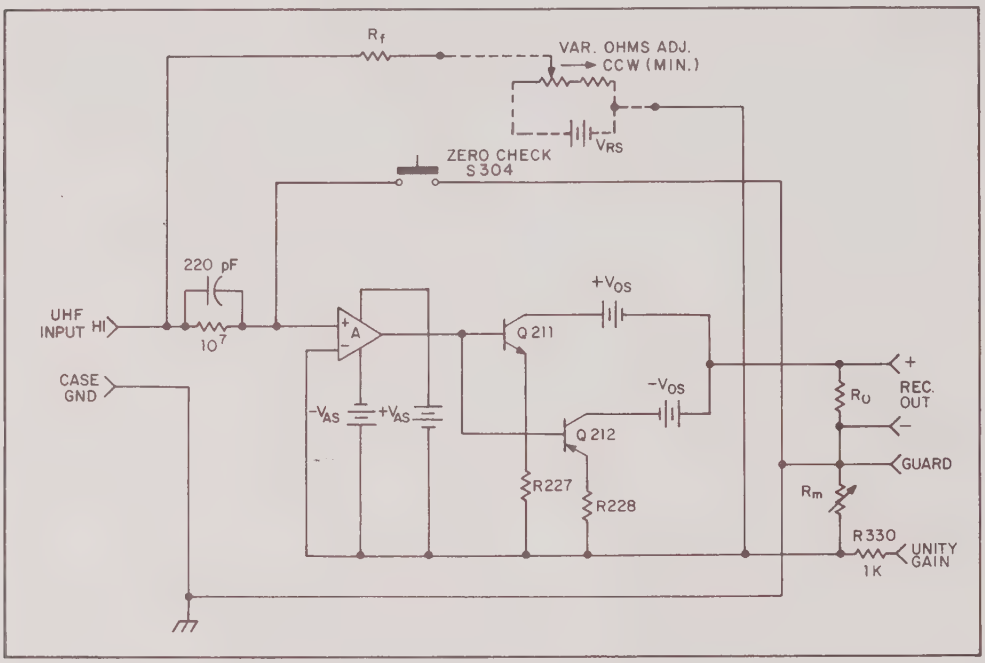

Figure A-4. MODEL 134 EQUIPPED WITH VARIABLE OHMS OPTION

A.2D INPUT CURRENT SUPPRESSION

The Input Current Suppression Option, #134/99, allows external current signals to be bucked out when the Model 134 is operated as a feedback ammeter. The control itself is a ten-turn screwdriver adjustment located at the rear panel and having a range of 100:1. The user selects the desired suppression range. Positive suppression only is available. The characteristics of the Current Suppression Option are indicated in Table A-2.

The proper value of R_S, the Zero Suppress resistor, is installed at the factory when the instrument is ordered with the Zero Suppress Option. When this resistor is a high-megohm type, 10^8 to 10^{11} ohms, it is fully tested and aged, and is specified to be accurate within ±2%. Note that the suppression current provided when the Suppression control is fully clockwise will be at least 2% greater than the specified maximum.

Suppression Range	R_S (ohms)	Resolution (typical)
10^{-6} to 10^{-8} A	10^6	2-to-4 x 10^{-9} A
10^{-7} to 10^{-9} A	10^7	2-to-4 x 10^{-10} A
10^{-8} to 10^{-10} A	10^8	2-to-4 x 10^{-11} A
10^{-9} to 10^{-11} A	10^9	2-to-4 x 10^{-12} A
10^{-10} to 10^{-12} A	10^{10}	2-to-4 x 10^{-13} A
10^{-11} to 10^{-13} A	10^{11}	3-to-6 x 10^{-14} A

Table A-2. INPUT CURRENT SUPPRESS OPTION CHARACTERISTICS

The input current suppression characteristic must be disabled (by removing R_S) if the instrument is to be used as a high-input impedance voltmeter since there will be a residual suppression current put out by the Model 134. This is true even when the rear-panel Suppression control is set to minimum. Further, attempts to use the Model 134 on the higher-sensitivity current ranges will result in increased current drift and noise unless R_S is removed. An applicable rule of thumb is that one should not select a higher sensitivity than the minimum current noted in the specific suppression range. For example, with a suppression range of 10^{-8} to 10^{-10} A, do not set the Range switch to a current below 10^{-10}.

NOTE: WHEN THE INPUT CURRENT SUPPRESSION AND VARIABLE DAMPING OPTIONS ARE BOTH INSTALLED IN THE MODEL 134, VARIABLE DAMPING WILL BE AFFECTED IN THAT MAXIMUM DAMPING CANNOT BE ACHIEVED. THE RISE TIME (MAXIMUM) IS GIVEN BY THE FOLLOWING FORMULA.

$$t_r = 2.2\ R_S C$$

where: R_S = suppression resistor installed
C = damping capacitor installed, 20 pF

FULL DAMPING CAN BE RESTORED BY REMOVING R_S.

Figure A-5 is a block diagram showing how the Input Current Suppression option is incorporated with the Model 134 operated in the feedback ammeter mode.

A.3 ACCESSORIES

A.3A INPUT BOARD

The Model 134/22 Input Board Accessory allows plug-in replacement of the input MOS device and protective circuitry. The 134/22 Input Board is a fully tested replacement component and, when installed in place of a defective Input Board, will restore the Model 134 to its original operating specifications. Figure A-6 is a photograph of the 134/22 Accessory.

A.3B PRECISION RESISTORS

High-megohm resistors, as noted below, are available as accessories to the Model 134. These resistors can be provided 'plain', or enclosed in shielded boxes with BNC input-output connectors.

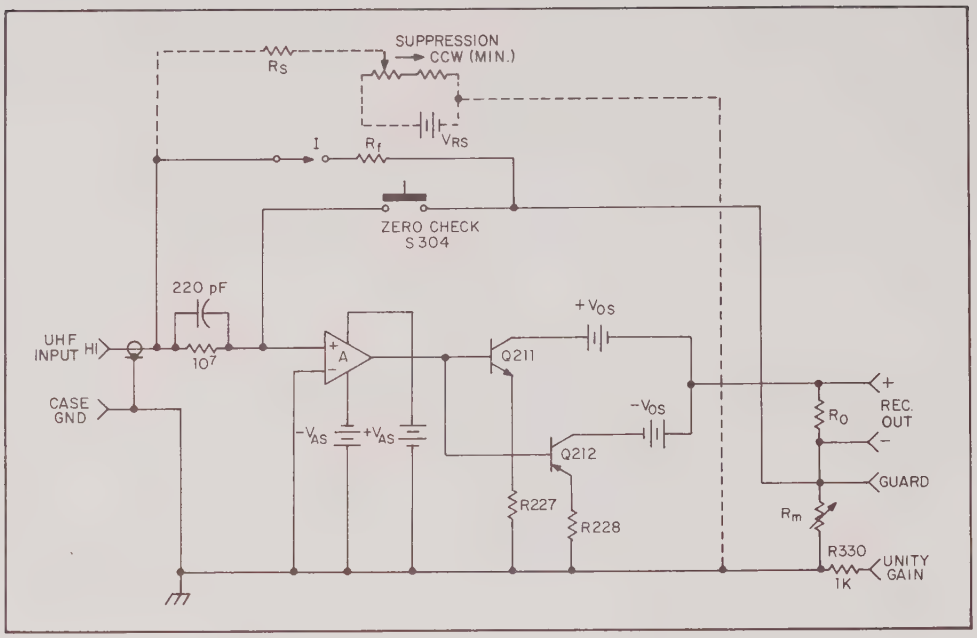

Figure A-5. MODEL 134 EQUIPPED WITH INPUT CURRENT SUPPRESSION OPTION

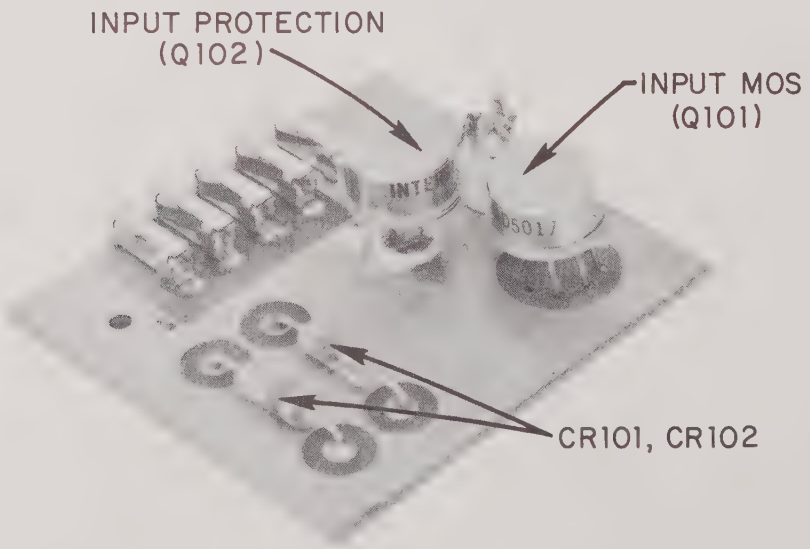

Figure A-6. INPUT BOARD ACCESSORY, #134/22

Resistor Value	Resistor Part #	Resistor Installed in Shielded Box, Accessory #
10^7 ohms	4741-0051-04	134/52
10^8 ohms	4741-0052-03	134/53
10^9 ohms	4741-0053-02	134/54
10^{10} ohms	4741-0054-01	134/55
10^{11} ohms	4741-0055-00	134/56
10^{12} ohms	4741-0056-09	134/57

Table A-3. ACCESSORY HIGH-MEGOHM RESISTORS

All resistors are fully tested and aged, and have a specified accuracy of ±1%. The unmounted resistors are suitable for in-circuit installation. The shielded resistors are suitable for convenient use in conjunction with the Model 134. Figure A-7 is a photograph showing four of the six shielded resistors available.

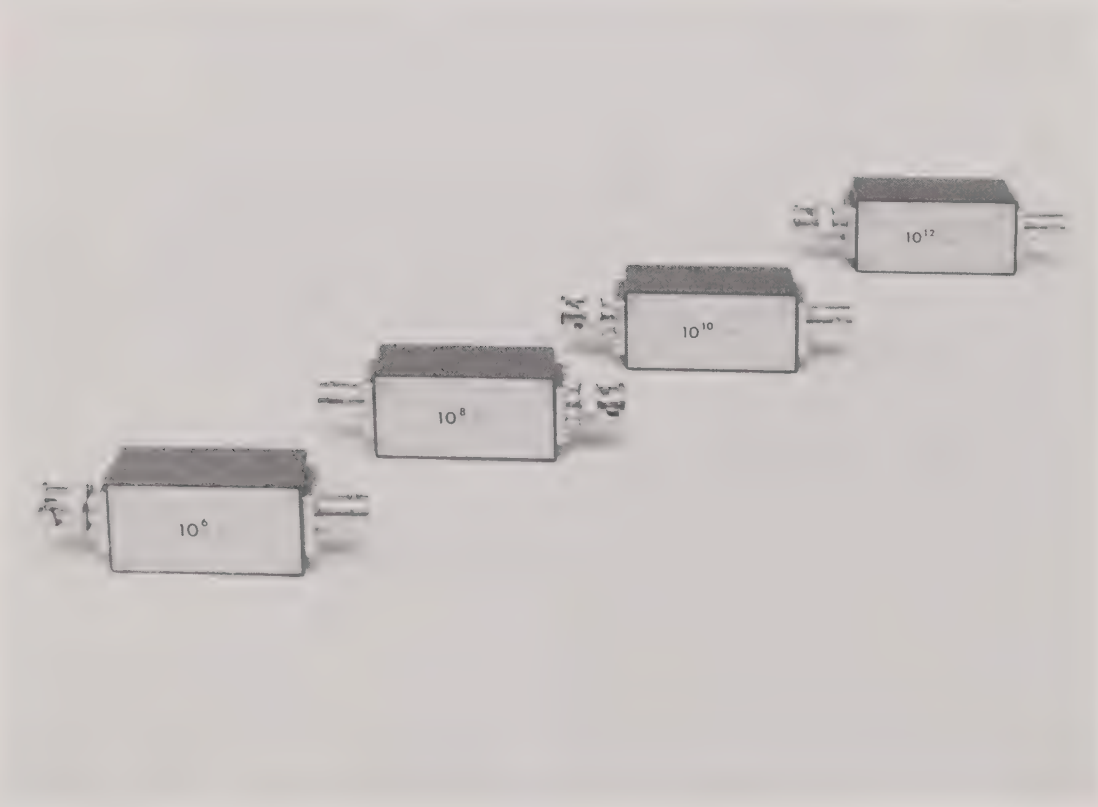

Figure A-7. ACCESSORY, PRECISION, SHIELDED, HIGH-MEGOHM RESISTORS

A.3C PROBES

There are two probes available for use with the Model 134. The Direct Probe, Accessory #134/60, is fully internally shielded with an input resistance of 10^{14} ohms. The 10:1 divider probe, Accessory #134/65, is also fully internally shielded, has an input resistance of 10^{10} ohms, and a divider ratio accuracy of ±2%. The divider voltage coefficient does not exceed 20 ppm/V, and the temperature coefficient of the divider ratio does not exceed 0.2%/°C from 25°C to 45°C. The 134/65 probe extends the Model 134 voltage range to 1000 V.

Both probes are fitted with thirty inches of RG-174U cable terminated in a male UHF plug.

Figure A-8 is a photograph of one of the probes. The external appearance of the two probes is the same.

A.3D ELECTROMETER CONNECTOR KIT

The Model 134/70 Electrometer Connector Kit contains an assortment of the more common connectors and cables used in electrometer measurements. All connectors, and the UHG plug to UHF plug cable, 6020-0058-04, are virgin-teflon insulated and suitable for use with the Model 134 in applications at the sensitivity limits of the instrument. The included 9201 UHF plug to alligator clip cable is for general-purpose low-impedance connections (up to 10^{10} ohms).

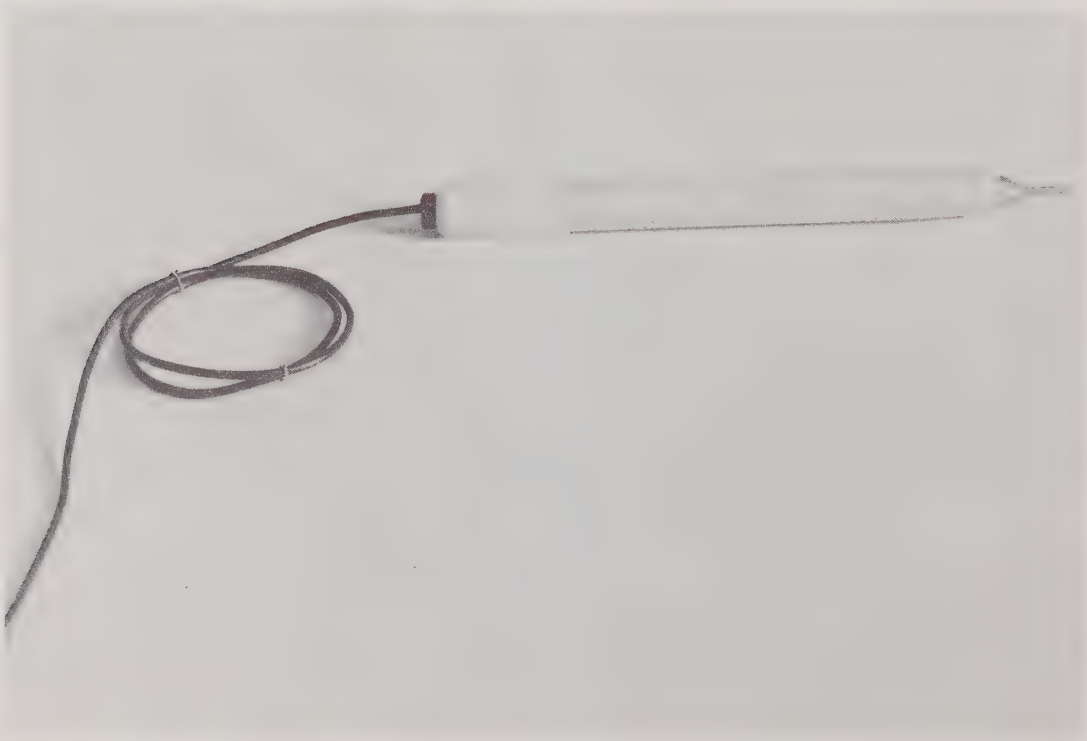

Figure A-8. ACCESSORY PROBE, #134/60 OR 134/65

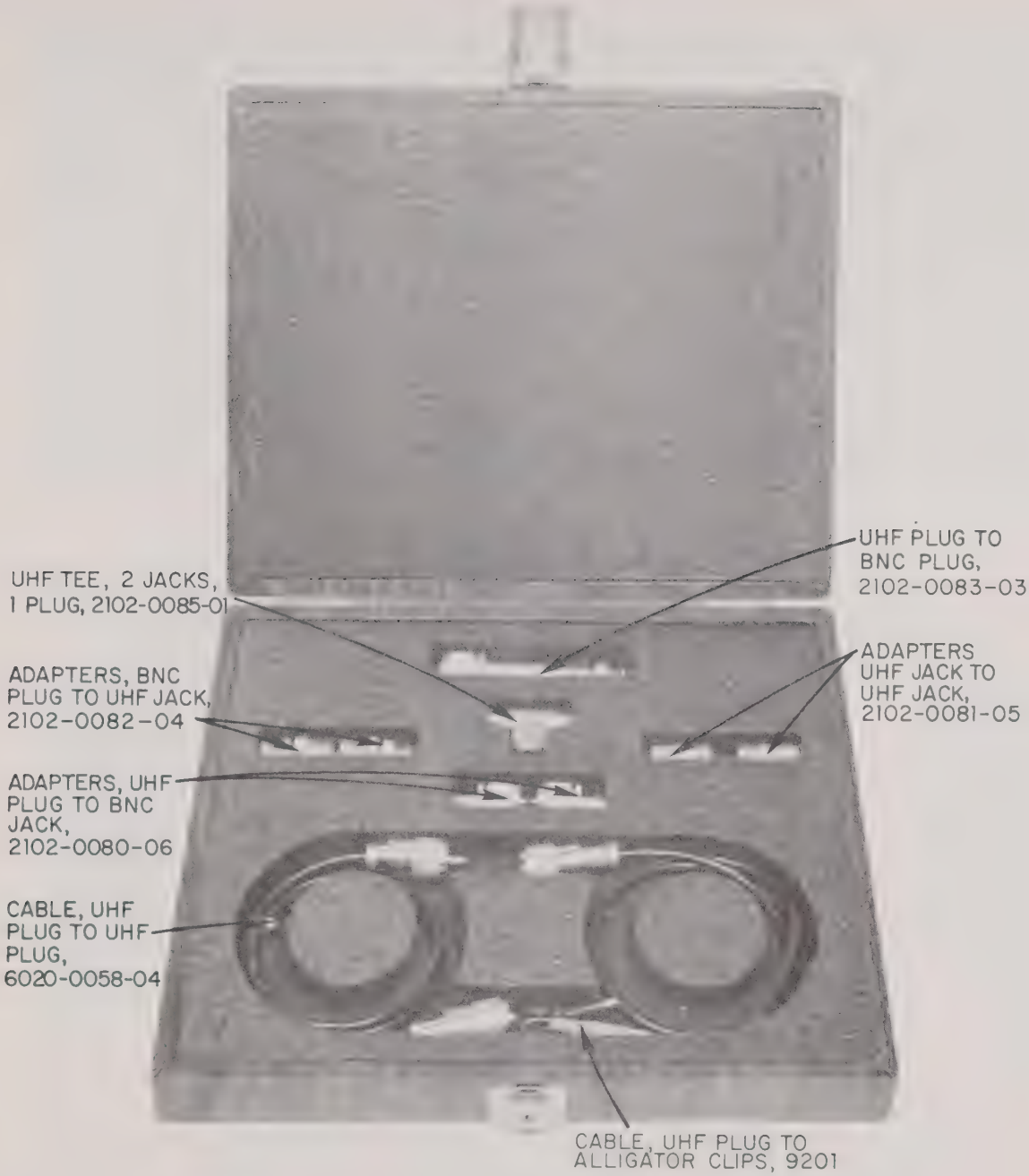
UHF TEE, 2 JACKS, 1 PLUG, 2102-0085-01
UHF PLUG TO BNC PLUG, 2102-0083-03
ADAPTERS, BNC PLUG TO UHF JACK, 2102-0082-04
ADAPTERS UHF JACK TO UHF JACK, 2102-0081-05
ADAPTERS, UHF PLUG TO BNC JACK, 2102-0080-06
CABLE, UHF PLUG TO UHF PLUG, 6020-0058-04
CABLE, UHF PLUG TO ALLIGATOR CLIPS, 9201

Figure A-9. ELECTROMETER CONNECTOR KIT, ACCESSORY #134/70

NOTE: EACH COMPONENT OF THE KIT IS SEPARATELY AVAILABLE.

Figure A-9 is a photograph of the kit showing the individual components and indicating the name and part number of each.

Figure A-10. SINGLE-UNIT RACK MOUNTING KIT, ACCESSORY #134/71

Figure A-11. DUAL UNIT RACK MOUNTING KIT, ACCESSORY #134/72

A.3E RACK MOUNTING KITS

Accessories #134/71 and 134/72 are single and dual rack-mounting kits respectively, each complete with the hardware required to mount the Model 134. To rack mount the Model 134, one must first drill four #8 holes in the top cover, in line with the holes on the internal top support bars. The rack-mounting angles provided with the kit are then fastened to the instrument, allowing it to be mounted. Figures A-10 and A-11 are photographs of the two kits.

A.3F GUARDED TEST BOX

The Model 134/75 Guarded Test Box is a fully shielded and guarded test enclosure for use in making low-level measurements on semiconductors, capacitors, etc. This accessory can be used in conjunction with the Model 134 to that instrument's limits of sensitivity. The Model 134/75 is easily dismantled and, if necessary, rewired to fit the users exact requirements. Sample holding and wiring clips are provided, along with cables and a UHF plug to BNC plug adapter, PAR part #2102-0083-03, for making rigid, vibration-free connections to the Model 134. Figure A-12 is a photograph of this accessory.

A.3G DIRECT CABLE

The Direct Cable, Accessory #9201, gives a convenient means of connecting the Model 134 to general-purpose low-impedance signal sources (source impedances up to 10^{10} ohms). This cable, while available as a separate accessory, is also included as one component of the Electrometer Connector Kit described earlier. Figure A-13 is a photograph of the direct cable.

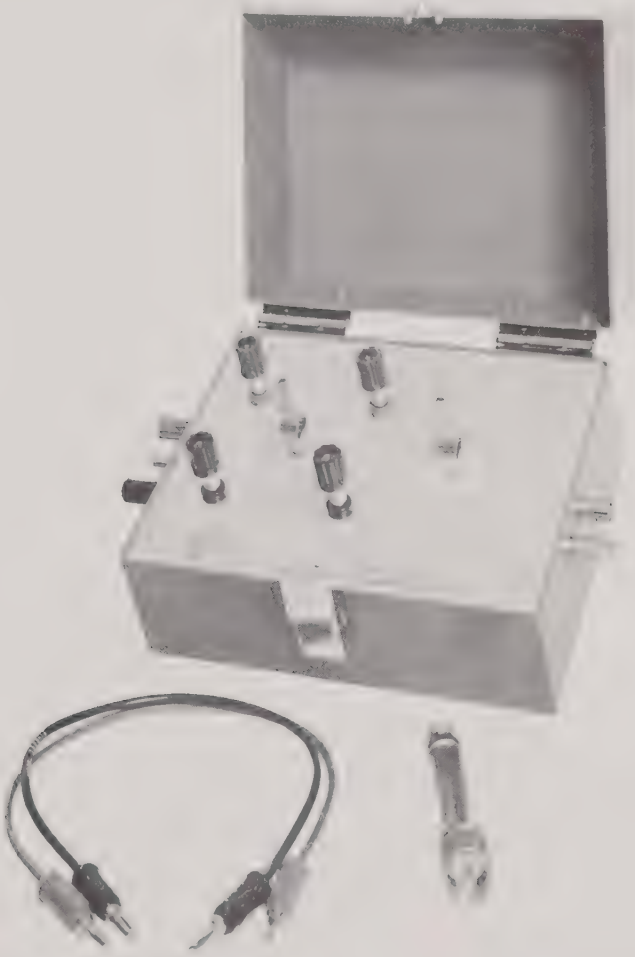

Figure A-12. GUARDED TEST BOX, ACCESSORY #134/75

Figure A-13. DIRECT CABLE, ACCESSORY #9201

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